ɔrt No. DOT/FAA/DS-88/09

MTR-88W125

(2)

A PROCEDURE FOR OPERATING EPENDENT INSTRUMENT APPROACHES TO CONVERGING RUNWAYS

AD-A204 713

DR. BERNARD LISKER

The MITRE Corporation
McLean, Virginia 22102

SEPTEMBER 1988

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Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
ADVANCED SYSTEM DESIGN SERVICE
Washington, D.C. 20591

NOTICE

Technical Report Documentation Page

2

1. Report No. DOT/FAA/DS-88/09

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

A Procedure for Operating Dependent Instrument Approaches to Converging Runways

5. Report Date September, 1988

6. Performing Organization Code

7. Author(s)

Dr. Bernard Lisker

8. Performing Organization Report No. MTR-88W125

9. Performing Organization Name and Address

The MITRE Corporation
7525 Colshire Drive
McLean, Virginia 22102

10. Work Unit No. (TRAIS)

11. Contract or Grant No. DTFA01-84-C-00001

12. Sponsoring Agency Name and Address

Department of Transportation
Federal Aviation Administration
Advanced System Design Service
Washington, D. C. 20591

13. Type of Report and Period Covered

14. Sponsoring Agency Code ADS-240

15. Supplementary Notes

16. Abstract

This report introduces an air traffic control procedure that allows two staggered streams of aircraft, flying under Instrument Flight Rules (IFR), to approach and land on converging runways. The staggered arrivals provide adequate separation assurance between aircraft in the event of consecutive missed approaches. Unlike existing converging approach procedures, the new procedure allows Decision Heights (DHs) down to 200 feet, yielding arrival capacity improvements from 4 to 63 percent over single-runway operations.

The report discusses currently approved converging approach procedures, their advantages and limitations, as well as the motivation for developing a new procedure. The new procedure is explained in detail and a 17-airport benefit analysis is included. That analysis concludes that the procedure introduced here can be implemented advantageously at several airports.

17. Key Words

Air Traffic Control, Approach Procedures, Airport Capacity, Converging Approaches, Airport Delays

19. Security Classif. (of this report) Unclassified

20. Security Classif. (of this page) Unclassified

21. No. of Pages

22. Price

ACKNOWLEDGEMENTS

I wish to express my appreciation to the individuals at MITRE that assisted me throughout this research effort. In particular, I am grateful to Dr. John N. Barrer, whose expertise in ATC and thoroughness were crucial to this task. Likewise, I wish to acknowledge the constant technical support and ever present encouragement of Dr. Agam N. Sinha. Special recognition is due to Drs. Anand D. Mundra and Arthur E. Salwin, who reviewed the entire draft and provided valuable comments that helped clarify important issues. I also want to thank Mses. Tracy L. Armstrong and Dayna Dick for their long hours of diligent work, typing and formatting this report.

At the FAA many individuals supplied helpful feedback during the preparation of this report. Without their field experience, this assignment would have not been accomplished. Special thanks to Messrs. Paul J. Best, Russ Gausman, and Gene Wong.

I dedicate this study to the dear memory of my unforgettable grandfather, Herschel Melman, whose spirit guides all my efforts.

EXECUTIVE SUMMARY

INTRODUCTION

As the 1980s draw to a close, U.S. aviation is going through a period of intense debate over the issue of airport capacity and delay. Many major U.S. airports are saturated due to large increases in aircraft traffic and there are few avenues to resolve this issue. The saturation problem occurs mainly when Instrument Flight Rules (IFR) are in effect and visual separation cannot be used.

Federal Aviation Administration (FAA) regulations generally require IFR operations whenever ceilings are below 1,000 feet. One way to alleviate airport capacity saturation under such ceilings is by the use of air traffic control (ATC) procedures that allow two aircraft streams to approach their respective runways simultaneously. Currently many airports do so by conducting IFR approaches to parallel runways. There are, however, airports that do not have parallel runways or for some reason cannot use them simultaneously (such as environmental problems, wind shifts, or runway closings). When that is the case, at some airports, approaches to converging runways can be an option. At least 74 out of 101 airports analyzed in a recent study (Reference ES-1) have one or more converging runway configurations in which runways intersect either physically or through their extended centerlines.

At least three airports currently conduct IFR approaches to converging runways. These are Chicago O'Hare, Denver, and Philadelphia. They all use two independent approaches, i.e., the two converging aircraft streams are operationally independent of each other. Consequently, the arrival capacity is equal to that of two single instrument approaches, or about 54 arrivals per hour (single-runway instrument approaches yield about 27 arrivals per hour). The minimum ceiling required by these procedures is site-specific. For example, Chicago O'Hare requires a 700-foot ceiling, while Denver requires 400 feet. However, in general, the procedures can be used only when ceilings are above 600 feet, thus restricting the periods of time during which converging procedures can be operated. When ceilings fall below 600 feet, airports that cannot operate parallel approaches are often left with only the option of operating single-runway approaches.

This report introduces a procedure that allows the operation of instrument approaches to converging runways when ceilings are as low as 200 feet (Category I minima). Reducing the ceiling minima can increase the average arrival capacity at many airports by increasing the periods of time during which multiple arrival streams can be used.

PROPOSED PROCEDURE

The main issue that arises out of simultaneously operating a pair of converging runways is the loss of adequate separation between two aircraft at the runways' intersection during the execution of simultaneous missed approaches. The proposed procedure's underlying idea is to stagger aircraft arrivals on each approach. The amount of stagger is calculated to provide adequate aircraft and wake-vortex separation if both aircraft execute missed approaches. The term "dependent" approach refers to procedures that, as the one presented in this report, prohibit the simultaneous landing of two aircraft.

The procedure can be operated in two modes, "non-conditional" and "conditional". One mode is called "non-conditional" because it allows aircraft on one approach to proceed to land if a missed approach is being executed on the other approach. The other mode is called "conditional" because aircraft on one approach must not be cleared to land (and instead must be ordered to turn) if a missed approach is being executed on the other approach.

Description of the Non-Conditional Mode

Time Stagger. Figure ES-1 shows two converging runways, 1 and 2, where the aircraft on approach to Runway 1 is the trailing aircraft while the one on approach to Runway 2 is the leading aircraft.

The non-conditional mode calls for straight-out missed approaches in order to keep the pilot workload at a normal level and to put both aircraft on diverging courses as soon as possible (after they pass the runways' intersection point). This minimizes the controller's workload. Aircraft are time staggered taking into consideration aircraft speeds and runway geometry so that in the event of consecutive missed approaches, aircraft will arrive at the intersection point at different times.

As long as converging aircraft arrive at the intersection at different times, separation is assured. It is also important to consider the possibility of a wake vortex encounter at the intersection. A preliminary analysis shows that a time separation of 50 to 90 seconds at the intersection may be adequate for most aircraft pairs.

The Gate. In order to achieve the desired time separation, a fix referred to as a "gate" (see Figure ES-1), is established on the final approach paths. The controller is to ensure that two aircraft (each on a different approach) are never allowed to be present simultaneously between their approach gate and missed approach point (MAP). The trailing aircraft will not be allowed to reach its gate before the leading aircraft has passed its MAP.

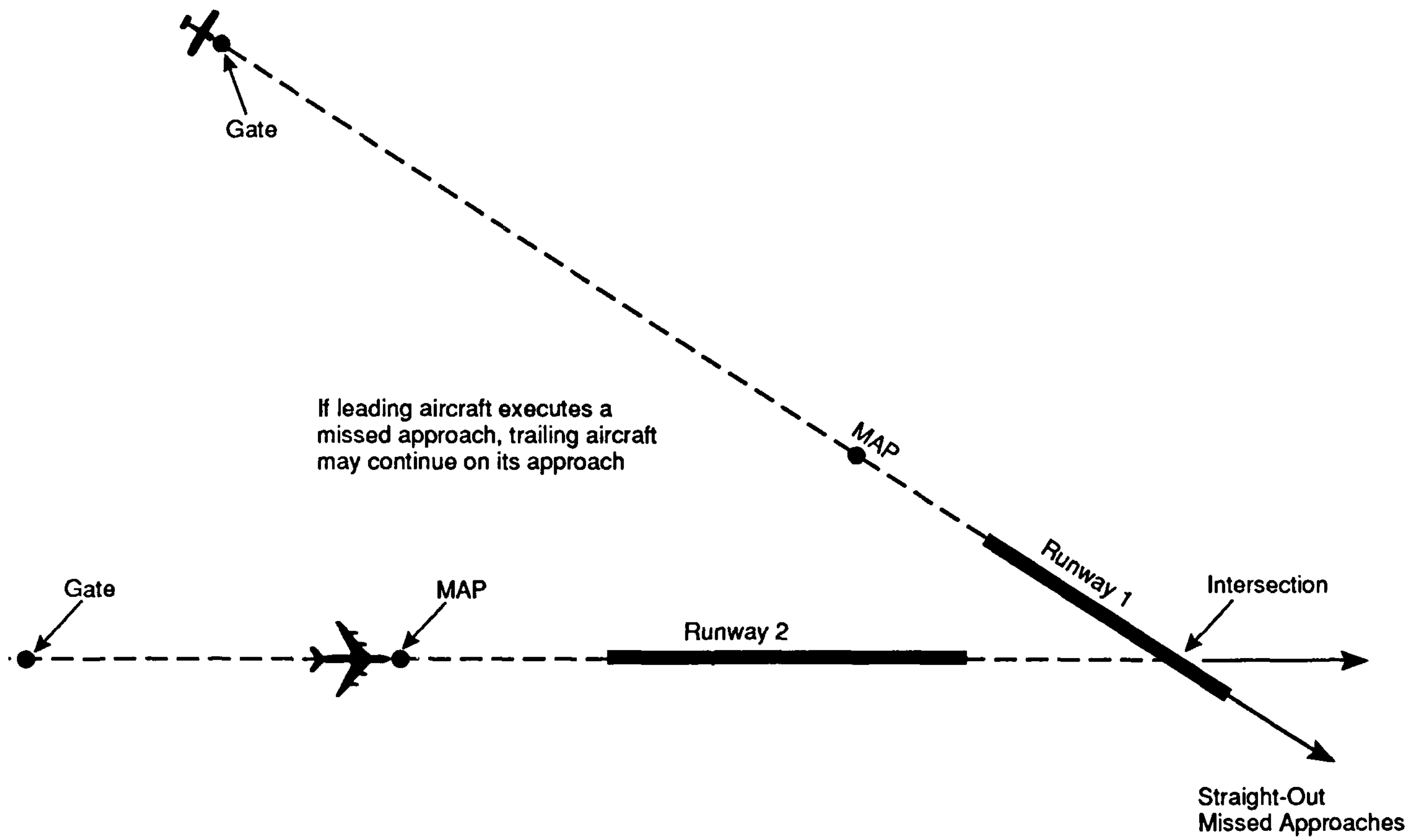

FIGURE ES-1
NON-CONDITIONAL DEPENDENT IFR APPROACHES TO CONVERGING RUNWAYS

The location of each gate is determined by the desired time separation at the intersection and the relative aircraft speeds. Theoretically, the gates' locations are movable because of their dependence on aircraft speeds. However, in practice, there is a possibility of placing the gates at fixed, "optimal" locations, in terms of wake vortex separation.

In order to help radar controllers maintain the stagger between approaching aircraft before their arrival at their gates, it is important to provide them with automated visual aids. A description of a computer-driven controller aid that promises to enable the implementation of the above-mentioned procedure can be found in Reference ES-2. The equations that describe the position of the gate on each converging approach have been developed and can be found in this report.

Description of the Conditional Mode

Distance Stagger. Figure ES-2 depicts the geometrical characteristics of the conditional mode (Reference ES-2). Just as in Figure ES-1, two aircraft are shown here, one leading and one trailing. And just as in the non-conditional case, the main objective is to provide adequate separation if aircraft on both approaches execute consecutive missed approaches. The non-conditional mode uses time as a basis to ensure separation on intersecting paths. The conditional mode, on the other hand, prevents the paths from intersecting altogether through the execution of turning missed approaches, as shown in Figure ES-2. To ensure that the turning paths do not overlap, the leading and trailing aircraft are staggered. The stagger is calculated so the turning TERPS obstacle surfaces do not overlap (for detailed information on TERPS surfaces, see Reference ES-3). Aircraft are assumed to stay within the boundaries of their corresponding TERPS surface. This ensures that their missed approach paths do not cross. The following paragraphs explain how an adequate stagger is determined.

Breakaway Point. A MAP is established on one approach (normally corresponding to a 200-foot decision height) while a breakaway point is determined for the other approach. The breakaway point is placed as close as possible to its corresponding threshold such that the turning TERPS surfaces, beginning at each of these points (MAP on one approach and breakaway point on the other approach), do not overlap (see Figure ES-2). The same method is used to determine the location of the breakaway point on each converging approach. The controller is to ensure that two aircraft (each on a different approach) are never allowed to be present simultaneously between their breakaway point and MAP. If the leading aircraft initiates a missed approach, the controller is required to order the trailing aircraft on the other approach to go-around at or before its breakaway point.

Unlike the non-conditional mode, in the case of conditional approaches, the location of the breakaway point is determined by the fixed

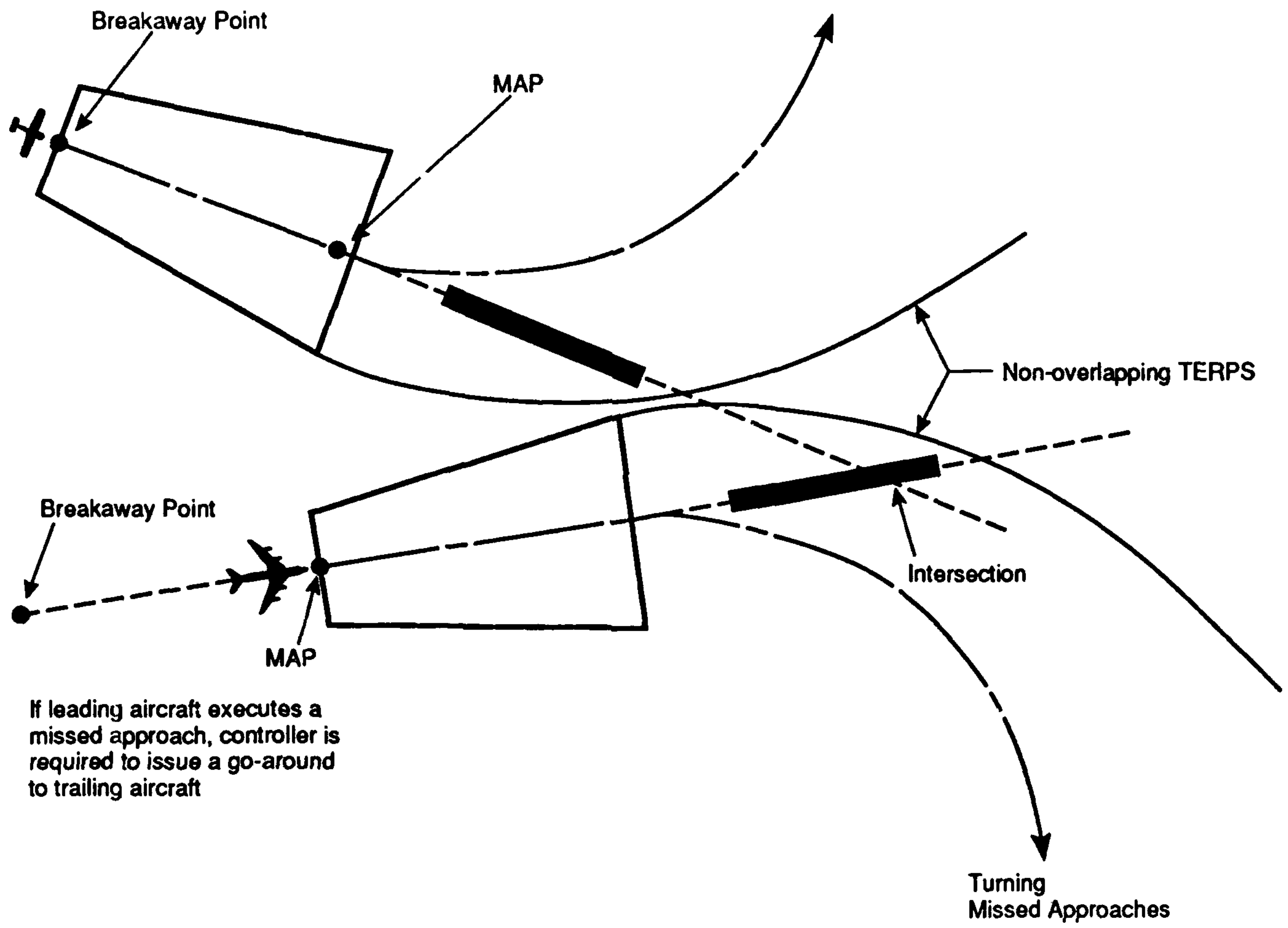

FIGURE ES-2
CONDITIONAL DEPENDENT IFR APPROACHES TO CONVERGING RUNWAYS

location of the MAPs and does not depend on the speed of approaching aircraft. In this case also, automated visual aids can help controllers maintain the stagger between aircraft.

POTENTIAL BENEFITS

The assessment of benefit provided by a new approach procedure is primarily given by its arrival capacity. In the case of dependent approaches to converging runways, the stagger between aircraft ultimately determines arrival capacity. The shorter the stagger, the larger the arrival capacity. That stagger is in turn governed by the breakaway-to-MAP or gate-to-MAP distance.

In the case of the conditional mode, the breakaway-to-MAP distance is fixed at each airport. Geometric factors completely define what that distance should be. On the other hand, in the case of the non-conditional mode, at any given airport, for each desired time separation at the intersection and approaching aircraft speeds, the gate will be at a specific distance from the MAP. A shorter time separation produces a shorter stagger and, therefore, larger arrival capacity. Thus, the question of how short the time separation can be is of great importance. As mentioned before, analysis has shown that a time separation of 50 to 90 seconds may be adequate to provide separation assurance for most aircraft pairs.

Using a somewhat restrictive selection criteria, 17 major U.S. airports may benefit from using the procedure described in this report. The selection criteria allows only airports with at least three runways, including a non-intersecting departure runway. Procedures must yet be developed to ensure time separation between departures and arrivals. Furthermore, the list includes only configurations whose runways are all 7,000 feet or longer in order to accommodate larger aircraft. If these selection criteria were relaxed, the list would include more airports.

Computer modeling has shown that the prime candidates to use the procedure are Boston, Denver, and St. Louis airports. The arrival capacity gain over single-runway IFR capacity of these airports was shown to be the following:

AIRPORT	NON-CONDITIONAL MODE	CONDITIONAL MODE
Boston	41%	44%
Denver	44%	48%
St. Louis	19%	11%

The other 14 airports on the list, with the exception of Anchorage, can also operate parallel approaches. Therefore, they can benefit from using the procedure proposed in this report only when their ceilings do not allow independent approaches to converging runways and, in addition, their

parallel configurations are not operative. Those airports are the following: Anchorage, Chicago, Dallas-Fort Worth, Dayton, Detroit, Washington Dulles, Honolulu, Memphis, Miami, New York's Kennedy, Oklahoma, Pittsburgh, Portland, and Tampa.

The proposed procedure would usually be utilized when two independent converging approaches cannot be conducted, nominally when ceilings are lower than 600 feet. While it may be argued that ceilings under 600 feet do not happen "frequently" at some airports, it should also be said that it is during such periods of time that most delays occur.

CONCLUSION AND RECOMMENDATIONS

The results of this work suggest that a significant number of airports would benefit from the application of the new procedure. Analysis has shown that the procedure can improve IFR arrival capacity for at least 17 U.S. airports from 4 to 63%, when controllers have no other alternative but to use single-runway approaches due to low ceilings or other conditions preventing them from using other procedures. Thus, dependent approaches to converging runways can constitute another aid in the controllers' box of tools used to increase overall airport capacity and to decrease delays.

This author recommends to go forward with the steps of test and evaluation of the proposed procedure. Practical implementation will require more work in the area of visual aids to the controllers as well as feedback from user and industry groups in order to refine the original concept and solve its limitations. At that point, site-specific studies will determine which airports should pioneer the use of the new procedure.

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ES-3 U.S. Department of Transportation (7 July 1976 plus changes), *United States Standard for Terminal Instrument Procedures (TERPS)*, FAA Handbook 8260.3B.

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1.0 INTRODUCTION

1.1 Background

As the 1980s draw to a close, U.S. aviation is going through a period of intense debate over the issue of airport capacity and delay. Many major U.S. airports are saturated due to large increases in aircraft traffic and there are few avenues to resolve this issue. The saturation problem occurs mainly when Instrument Flight Rules (IFR) are in effect and visual separation cannot be used.

Federal Aviation Administration (FAA) regulations generally require IFR operations whenever ceilings are below 1,000 feet. One way to alleviate airport capacity saturation under such ceilings is by the use of air traffic control (ATC) procedures that allow two aircraft streams to approach their respective runways simultaneously. Currently many airports do so by conducting IFR approaches to parallel runways. There are, however, airports that do not have parallel runways or for some reason cannot use them simultaneously (such as environmental problems, wind shifts, or runway closings). When that is the case, at some airports, approaches to converging runways can be an option. At least 74 out of 101 airports analyzed in a recent study (Reference 11) have one or more converging runway configurations in which runways intersect either physically or through their extended centerlines.

At least three airports currently conduct IFR approaches to converging runways. These are Chicago O'Hare, Denver, and Philadelphia. They all use two independent approaches, i.e., the two converging aircraft streams are operationally independent of each other. Consequently, the arrival capacity is equal to that of two single instrument approaches, or about 54 arrivals per hour (single-runway instrument approaches yield about 27 arrivals per hour). The minimum ceiling required by these procedures is site-specific. For example, Chicago O'Hare requires a 700-foot ceiling, while Denver requires 400 feet. However, in general, the procedures can be used only when ceilings are above 600 feet, thus restricting the periods of time during which converging procedures can be operated. When ceilings fall below 600 feet, airports that cannot operate parallel approaches are often left with only the option of operating single-runway approaches.

1.2 Purpose and Scope

This report proposes an IFR approach procedure for converging runways. The procedure allows operations down to Category I minima (ceilings down to 200 feet). This increases the total amount of time during which converging approaches can be handled (in comparison to previous procedures) and, therefore, average arrival capacity is increased. The procedure's development is described in detail to allow the reader to understand its

basic underpinnings. However, for those readers not interested in the development of the procedure but in the procedure itself, a conceptual explanation of it has been included. Beyond this introduction, the reader is assumed to be versed in the fundamental terminology of air traffic control. Uncommon terminology, however, is always explained.

Even though this report's main objective is to describe an approach procedure in a general manner rather than as applied to a particular airport, a 17-airport benefit analysis has been included. Yet, it is a high-level analysis, not a comprehensive examination of each airport. The latter is beyond the scope of this report.

1.3 Organization

The following information should help those interested in a particular section. This report contains five main sections and three appendices.

Section 2 is a discussion on the general subject of approaches to converging runways and related capacity issues. The section focuses on IFR procedures that have been approved and are taking place today, describing their limitations and the motivation for new, improved procedures.

Section 3 is the main core of this report. It discusses conceptually and analytically a procedure that allows lower ceilings during which approaches to converging runways can be operated. The section includes a description of the basic conceptual ideas behind the procedure, its mathematical representation, as well as some issues.

In Section 4, a 17-airport benefit analysis is presented. As mentioned before, this is a high-level analysis. Its aim is to show the range of potential capacity benefits provided by the proposed procedure for a wide variety of airports. This section also includes an analysis of the issues involved in the calculation of converging approach arrival capacity.

Section 5, the conclusion, attempts to bring forth a realistic assessment of the implementation and overall potential of the proposed procedure. A 3-part appendix section follows. There, among other things, a draft FAA Order to implement the procedure is introduced. The report concludes with a bibliography and a glossary.

2.0 APPROACHES TO CONVERGING RUNWAYS: CURRENT PROCEDURES

This section is an introduction to the subject of approaches to converging runways. After defining what converging runways are, IFR approaches to converging runways are dealt with, focusing on currently-approved procedures and their limitations. A good understanding of these limitations should provide the reader with a better appreciation of related capacity issues and the motivation for developing new procedures.

2.1 Converging Runways and Missed Approaches

Two runways are considered to be converging when they have an included angle from 15 to 100 degrees (Reference 1). Converging runways intersect either physically or through their extended centerlines.

The main issue that arises out of simultaneously operating a pair of converging runways is the loss of adequate separation between two aircraft at the runways' intersection during the execution of simultaneous missed approaches.

2.2 Types of Converging Approaches

Figure 1 depicts four types of approaches to converging runways. Notice in particular the intersecting approach case. Since Visual Flight Rules (VFR) operations are normally not allowed for this type of approaches, it was decided not to include intersecting approaches in this report's IFR analysis. The other approaches of Figure 1 are within the boundaries of this work.

2.3 VFR Approaches to Converging Runways

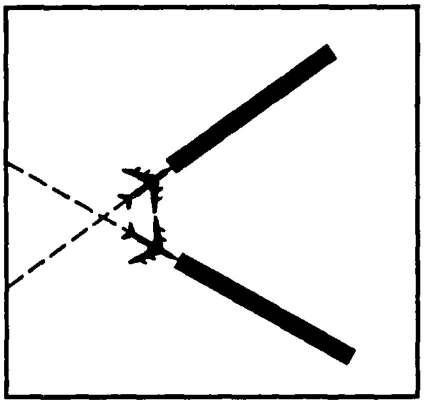
In general, when ceiling/visibility conditions are greater than 1000 feet/3 miles, visual approach clearances to converging runways are authorized.

2.3.1 Capacity Implications (VFR Approach Procedures)

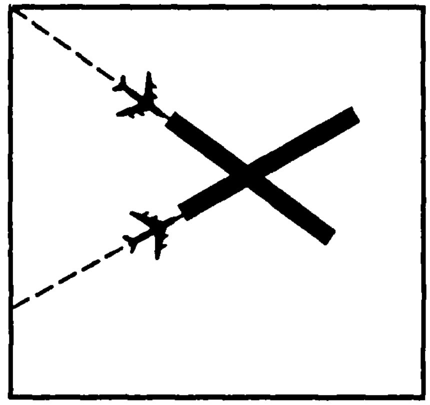
Under VFR, the arrival capacity of two converging runways can be as high as 72 arrivals per hour if the runways do not intersect and as low as about 36 arrivals per hour (the same capacity of a VFR approach to a single runway) if the runways intersect at a point close to their thresholds (Reference 6).

2.4 IFR Approaches to Converging Runways

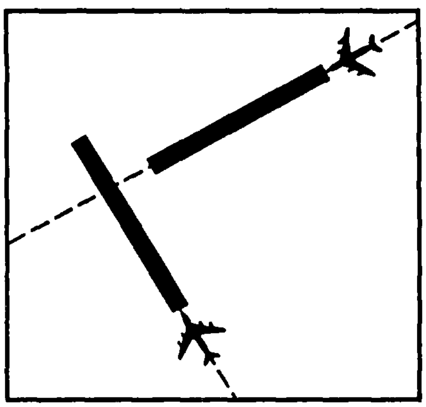
When ceiling and visibility conditions require IFR procedures, but meteorological conditions are close to the IFR/VFR boundary (a 1000-foot ceiling), some airports operate approaches to converging runways. Such



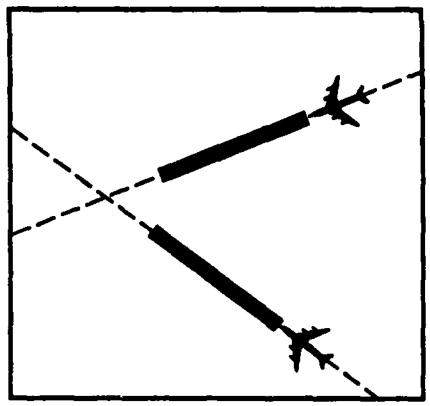
Intersecting Approaches



Intersecting Runways



Runway Intersecting an
Extended Centerline



Intersecting Centerlines

FIGURE 1
TYPES OF CONVERGING APPROACHES

approaches are conducted according to airport-specific orders and the two converging aircraft streams are handled as two independent single approaches. For that reason, they are referred to as independent approaches. Sections 2.4.2.1 and 2.4.2.2 describe two independent IFR approach procedures to converging runways. Dependent approaches, on the other hand, place separation requirements upon the converging streams (actions by one aircraft can limit actions by the other) that lead to a loss in capacity when compared to independent streams of traffic.

The following is a list of desirable characteristics in any converging IFR approach procedure:

1. Independent Streams. This concept was explained above. It leads to larger arrival capacity because no separation constraints are placed between the two aircraft streams. Hence, capacity is twice that of a single runway. Clearly, independent streams are always preferred. However, analysis has shown that independent streams exclude the implementation of the three characteristics listed below.

2. Straight-Out Missed Approaches. An IFR converging approach procedure that calls for straight-out missed approaches is preferred to procedures calling for turning missed approaches. A straight-out missed approach keeps the pilot workload at a normal level, and also puts both aircraft on diverging courses as soon as possible (as soon as they pass their runway intersection point), minimizing controller workload, too (see Figure 2).

3. Low Decision Height (DH). The lower the DH, the longer the amount of time that the procedure can be used. Ideally, an IFR converging approach procedure should allow Category I minima, which for most airports are a ceiling/visibility of 200 feet/0.5 miles.

4. No Procedural Constraints Between Streams. Procedural constraints are to be avoided. An example of this is (see Section 3) a procedure that (in one of its modes) requires a go-around on one approach if a missed approach is being executed on the other approach. Such constraints can disrupt orderly traffic on both converging streams and therefore are not desirable. Procedures that impose procedural constraints are referred to in this report as "conditional". Otherwise they are referred to as "non-conditional".

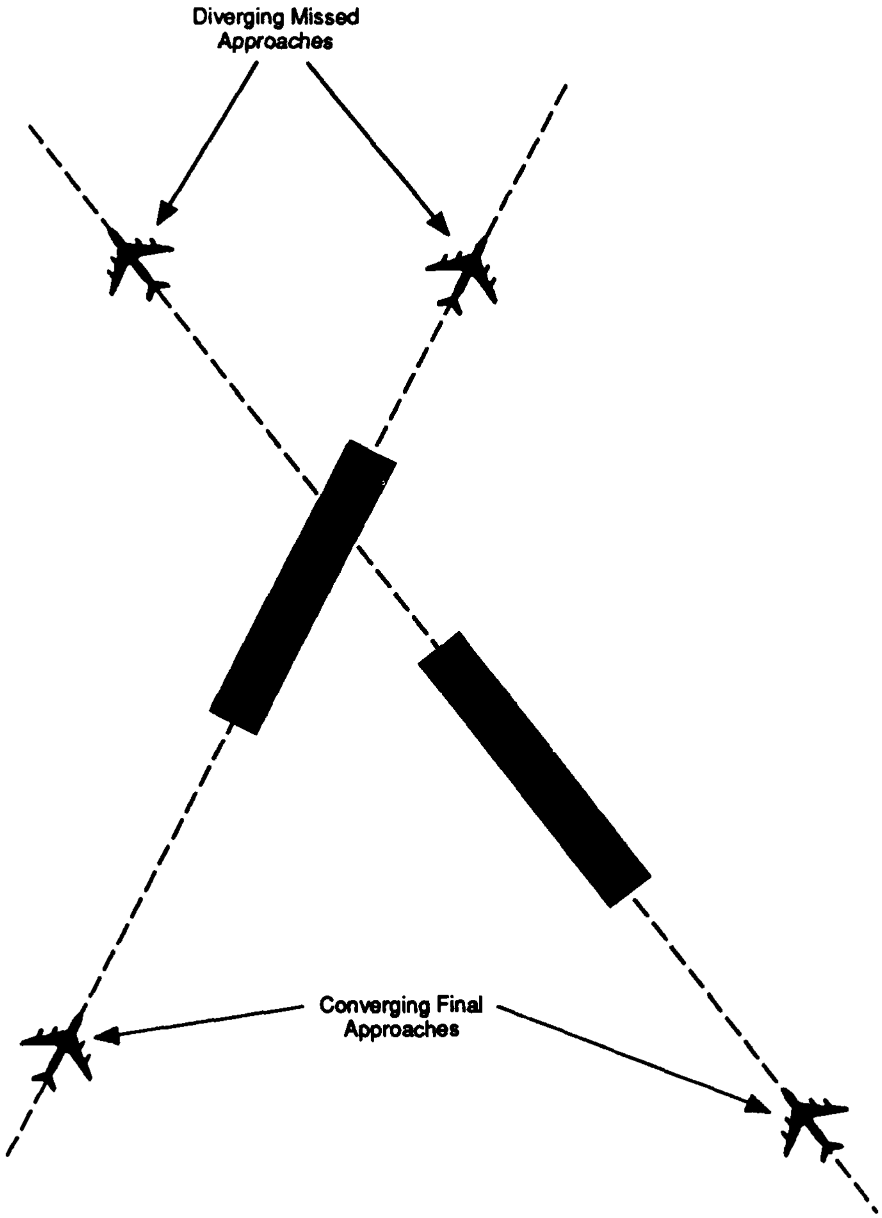


FIGURE 2
STRAIGHT-OUT MISSED APPROACHES

No current IFR converging approach procedure satisfies all four conditions listed above. Those conditions provide a guideline of desirable features to look for in new procedures. The procedures should yield at least two results:

1. Provide adequate separation assurance and wake vortex protection if both aircraft execute missed approaches.

2. Allow an arrival rate such that the total capacity of the two converging approaches be larger than single-runway IFR capacity (which is about 27 arrivals per hour).

2.4.1 Capacity Implications (IFR Approach Procedures)

Independent IFR approaches to converging runways (see Section 2.4) yield twice the arrival capacity of IFR approaches to a single runway because they are equivalent to two independently operated runways (about 54 arrivals per hour). When constraints are added to a converging approach procedure, arrival capacity decreases. If too many constraints are added, arrival capacity may reach the level of a single stream (about 27 arrivals per hour). At that or lower capacity levels, the benefit of operating two streams ceases and it becomes preferable to operate a single stream.

2.4.2 Marginal-IFR Approaches to Converging Runways: Current Practice

2.4.2.1 Tower-Applied Visual Separation Procedure. For many years, Chicago O'Hare Airport has operated an independent converging approach procedure during marginal IFR weather. It is sometimes referred to as the Chicago O'Hare "Duals" procedure. The minimum ceiling/visibility allowed for this procedure is 700 feet/2 miles (Reference 3).

This procedure operates as follows (see Figure 3). One runway is designated as the "primary runway" while the other (converging) runway is designated as the "secondary runway". Aircraft approaching the primary runway are allowed to proceed undisturbed until they land, independent of aircraft approaching the secondary runway. Hence, this is an independent approach procedure from the point of view of aircraft approaching the primary runway. However, aircraft on final approach to the secondary runway are required to report runway in sight when they pass a fix referred to as the "breakaway point". If either the pilot is able to see the runway at that point or the controllers can see the aircraft, a clearance to land is issued. If neither of these two conditions occurs, a missed approach procedure is to be executed at the request of the controller.

The breakaway point is defined as the point at which the secondary final approach first comes within 3 nmi of the primary approach. If missed

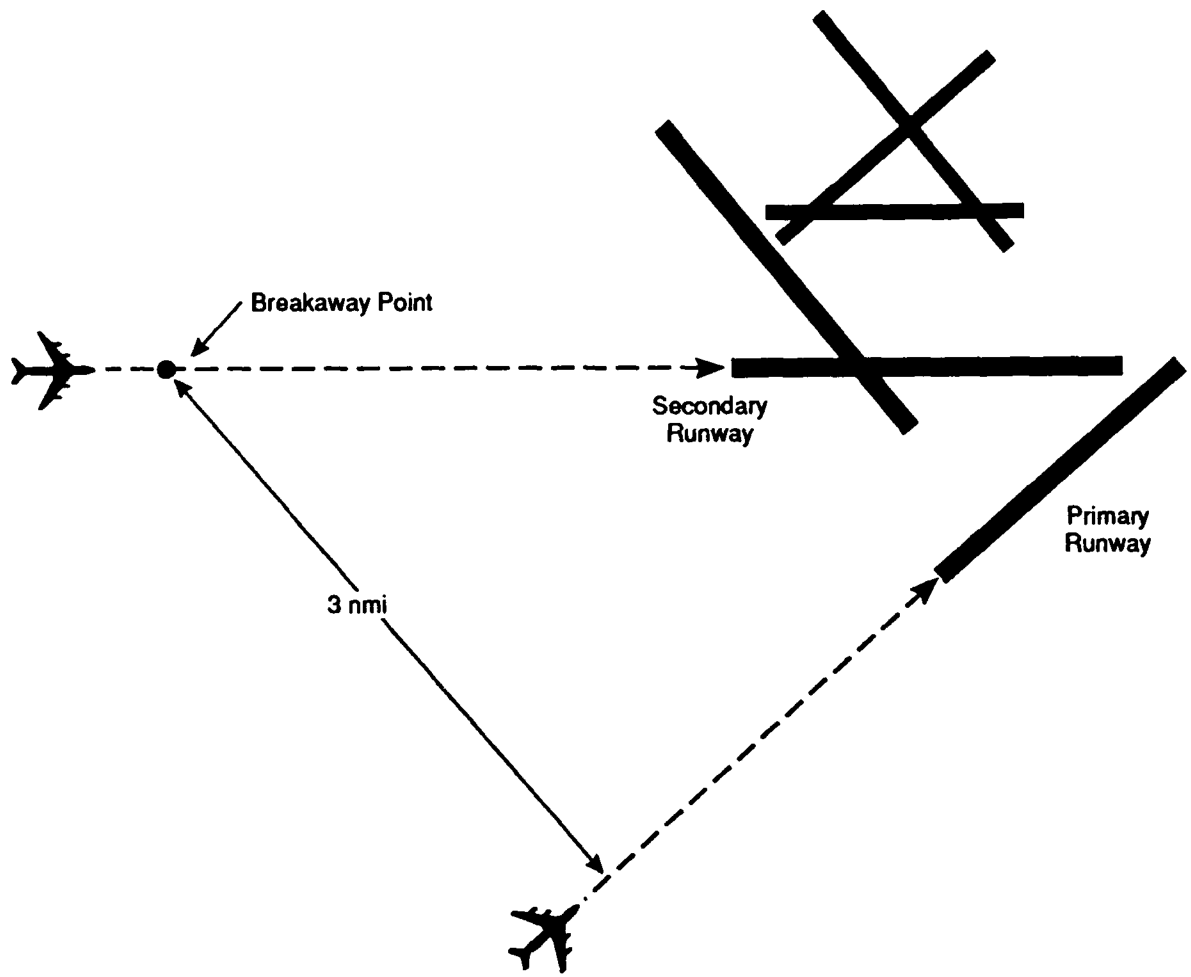


FIGURE 3
CHICAGO O'HARE "DUALS" PROCEDURE

approaches are executed on both approaches, tower applied visual separation in addition to the 3 nmi separation provided by the breakaway point are used to keep the two aircraft apart.

2.4.2.2 **TERPS+3 Procedure.** In April of 1986, The FAA issued Order 7110.98 (see Appendix B) to establish a new procedure "for conducting simultaneous instrument approaches to converging runways in instrument weather conditions". The procedure has been approved for operation at Denver and Philadelphia.

The main idea behind this procedure is that of using non-overlapping TERPS obstacle clearance surfaces (see Reference 5) as a means of separation for aircraft executing simultaneous missed approaches. It is assumed that each of the two aircraft executing a turning missed approach can keep its course within the limits of its respective TERPS surface. Each of the two TERPS surfaces is drawn starting at its respective missed approach point (MAP) (see Figure 4). The procedure also requires a 3-nmi separation between the MAPs on both approaches. TERPS+3 (as this procedure is often referred to) requires no dependency between the two aircraft on the converging approaches. Hence, it is an independent approach procedure.

In order to place the MAPs 3 nmi apart from each other and ensure non-overlapping TERPS surfaces, the MAPs have to be moved back, away from the runways' thresholds. As Figure 5 shows, moving the MAPs back increases separation between the TERPS surfaces and results in higher DHs.

One limitation of the procedure, however, is that many runway configurations require DHs higher than 600 feet to satisfy the TERPS+3 criterion (Reference 3). That, of course, restricts the availability of the procedure to weather conditions close to the VFR/IFR boundary. The procedure is not allowed if the converging runways intersect, unless controllers can establish visual separation and the ceiling/ visibility is above 700 feet/2 miles.

Section 3 introduces a procedure that deals with some of the restrictions of the procedures discussed above.

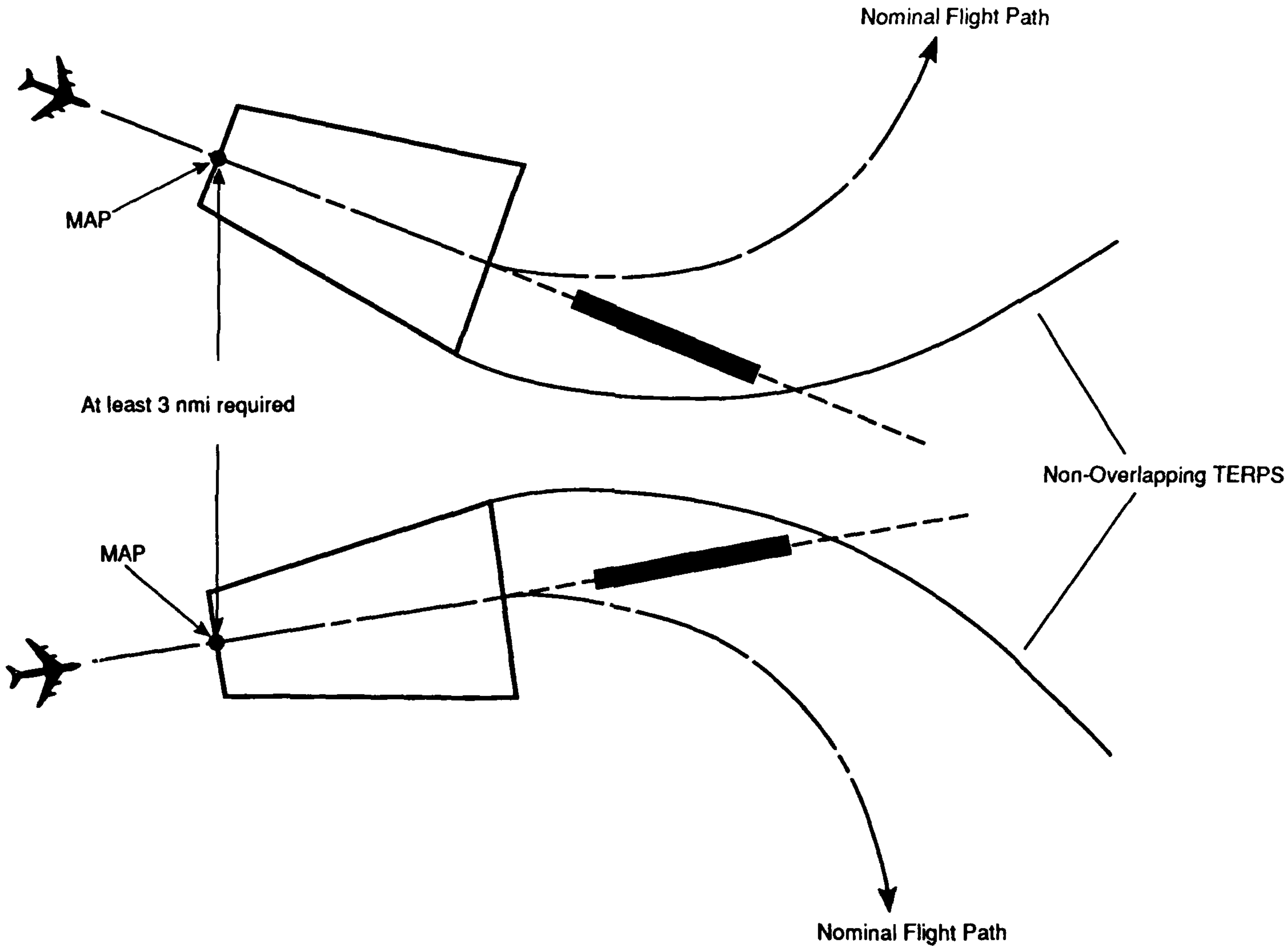
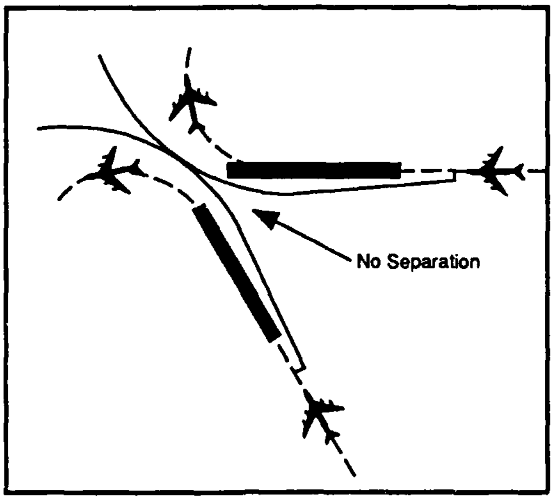
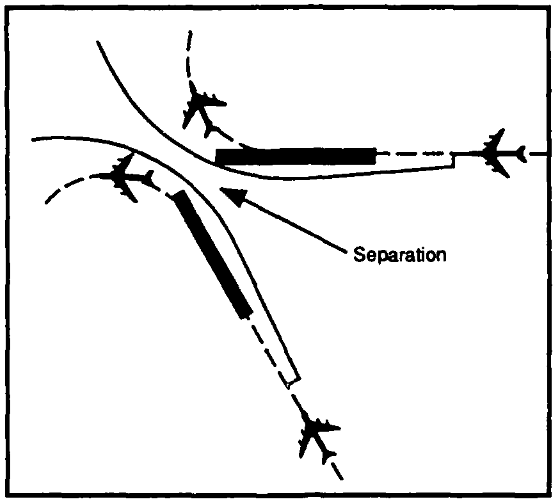


FIGURE 4
TERPS+3 PROCEDURE



Decision Height = 200 ft



Decision Height = 300 ft

FIGURE 5
MISSED APPROACHES TO CONVERGING RUNWAYS ILLUSTRATING INCREASE IN SEPARATION DUE TO INCREASE IN DECISION HEIGHT FROM 200 FEET TO 300 FEET

3.0 A NEW PROCEDURE FOR CONDUCTING IFR APPROACHES TO CONVERGING RUNWAYS

Section 2 has shown that current IFR converging approach procedures are hampered by relatively high DH requirements, often above 600 feet. While those procedures yield good arrival capacity (up to 54 arrivals per hour), their applicability is restricted by runway configuration and weather ceiling considerations. This section deals with the above-mentioned problems. A dependent converging approach procedure is proposed.

3.1 Objectives of the New Procedure

1. To provide rules that are applicable to varying runway configurations, including the case of intersecting runways.

2. To allow DHs lower than those provided by existing independent approach procedures, such as TERPS+3. Whenever possible, to lower DHs down to Category I minima.

3. To provide adequate aircraft separation in the event of consecutive missed approaches, without a substantial increase of workload for pilot and/or controller.

3.2 Main Elements of the New Procedure

The proposed procedure's underlying idea is to stagger aircraft arrivals on each approach. The amount of stagger is calculated to provide adequate separation assurance and wake vortex protection if both aircraft execute missed approaches. The term "dependent" approach refers to procedures that, as the one presented in this report, prohibit the simultaneous landing of two aircraft. The proposed procedure can be operated in two modes, "non-conditional" and "conditional".

3.2.1 Main Elements of the Non-Conditional Dependent Approach Mode

One mode is called "non-conditional" because it allows aircraft on one approach to proceed to land if a missed approach is being executed on the other approach.

The non-conditional mode calls for straight-out missed approaches in order to keep the pilot workload at a normal level and to put both aircraft on diverging courses as soon as possible (after they pass the runways' intersection point). This minimizes controller workload.

3.2.2 Main Elements of the Conditional Dependent Approach Mode

Another mode is called "conditional" because aircraft on one approach must not be cleared to land (and instead must be ordered to turn) if a missed approach is being executed on the other approach. The conditional mode calls for turning missed approaches.

3.3 Description of the Procedure

This section describes the development and operation of dependent approaches to converging runways: the determination of fixes, pilot and controller procedures, and terminology. The non-conditional and conditional modes are described in Sections 3.3.1 and 3.3.2, respectively.

3.3.1 Non-Conditional Mode

3.3.1.1 **Time Stagger.** Figure 6 shows two converging runways, 1 and 2, where Runway 1 intersects with the extended centerline of Runway 2. For this section's purposes, the aircraft on the approach to Runway 1 is the trailing aircraft while the one on the approach to Runway 2 is the leading aircraft.

Aircraft are time staggered taking into consideration aircraft speeds and runway geometry so that in the event of consecutive missed approaches, aircraft will arrive at the intersection point at different times. The time difference at the intersection is referred to as "time separation".

As long as converging aircraft arrive at the intersection at different times, separation is assured. It is important, however, to consider not only aircraft separation, but also the possibility of a wake vortex encounter at the intersection if the time separation is not large enough. A preliminary analysis (Section 4.3) has shown that a time separation at the intersection of 50 to 90 seconds may be adequate for most aircraft pairs.

3.3.1.2 **The Gate.** In order to achieve the desired time separation, a fix, referred to as a "gate" (see Figure 6), is established on the final approach paths. The controller is to ensure that two aircraft (each on a different approach) are never allowed to be present simultaneously between their approach gate and MAP. The trailing aircraft will not be allowed to reach its gate before the leading aircraft has passed its MAP.

The location of each gate is determined by the desired time separation at the intersection and the relative aircraft speeds. If an aircraft executes a missed approach, it will be required to execute a straight-out missed approach. The location of the gate on the opposite approach guarantees that if the trailing aircraft also executes a (straight-out) missed approach (at or before its MAP), it will reach the intersection after the leading aircraft has passed it.

If for any reason the trailing aircraft arrives at its gate before the leading aircraft gets to its MAP, the controller is required to issue an immediate go-around to the trailing aircraft.

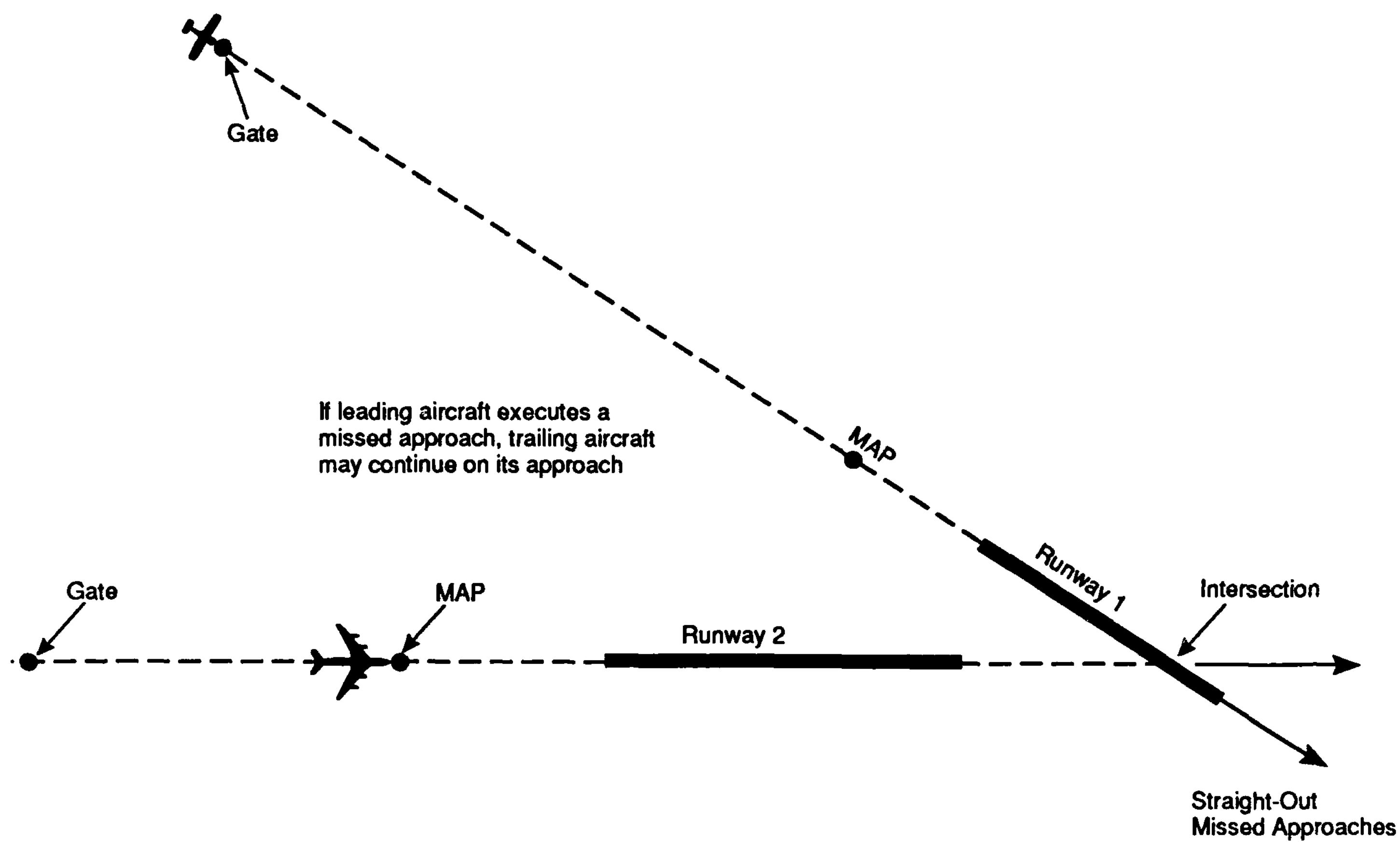


FIGURE 6
NON-CONDITIONAL DEPENDENT IFR APPROACHES TO CONVERGING RUNWAYS

3.3.1.2.1 **Gate Location Equation.** It follows, from the past few sections, that it is necessary to develop an equation to describe the position of the gate on each converging approach.

Both gates are calculated the same way. The gate location on approach 1 is G_1, defined as the distance (in feet) from the gate to the runway threshold on approach 1. G_1 is a function of the following variables (see Figure 7):

- t_1 = time (in seconds) required by aircraft on approach 1 to fly from the gate to the intersection.
- t_2 = time (in seconds) required by aircraft on approach 2 to fly from the MAP to the intersection.
- R_1 = distance (in feet) from the threshold of runway 1 to the intersection.
- R_2 = distance (in feet) from the threshold of runway 2 to the intersection.
- M_1 = distance (in feet) from the MAP to the runway threshold on approach 1.
- M_2 = distance (in feet) from the MAP to the runway threshold on approach 2.
- $V_{1(FA)}$ = final approach speed (in feet/second) of aircraft 1
- $V_{2(FA)}$ = final approach speed (in feet/second) of aircraft 2
- $V_{1(MA)}$ = missed approach speed (in feet/second) of aircraft 1
- $V_{2(MA)}$ = missed approach speed (in feet/second) of aircraft 2

The distances and speeds above reflect horizontal components only.

In developing the equation, the following assumptions were made:

- The DHs on both approaches are considered to be located at the same altitude. Category I minimum approaches are normally allowed (i.e., 200-foot-high DHs). The exception to this is the case of airports that for reasons such as obstacles or noise, do not allow 200-foot DHs. Boston, for instance, requires a DH much higher than 200 feet on one of its approaches.

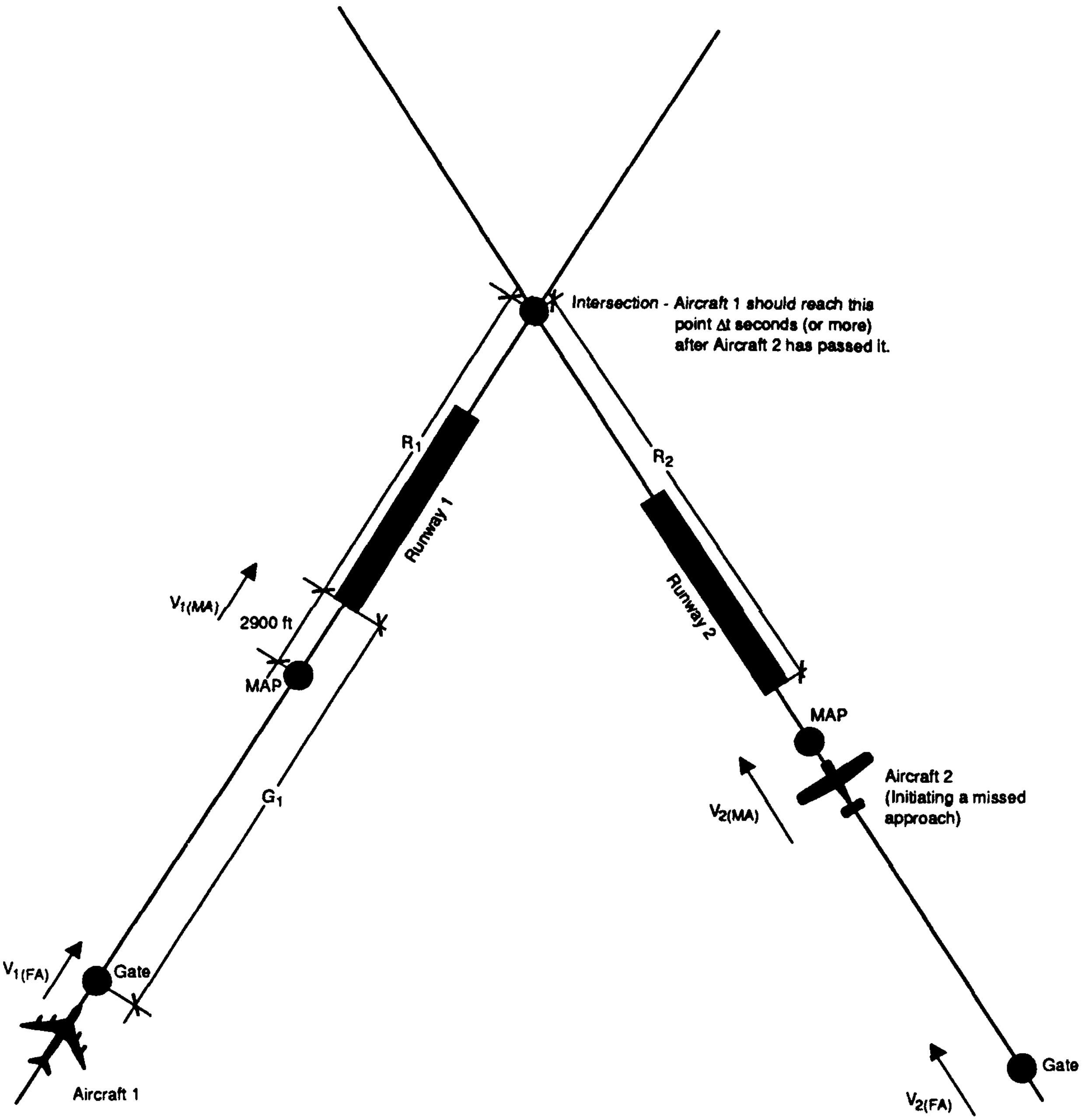


FIGURE 7
THE GATE CONCEPT

- It is assumed that a 3-degree glide slope is used on final approach, crossing the runway threshold at a height of 50 feet. The MAPs are located at a 2862-foot horizontal distance from their respective runway threshold and at an altitude of 200 feet. For simplification, the 2862-foot value has been rounded to 2900 feet. Therefore, $M_1 = M_2 = 2900$ feet.

- It is assumed that the missed approach speed of a given aircraft is a function of its final approach speed. Let $V_{(FA)}$ = final approach speed, $V_{(MA)}$ = missed approach speed and $V_{(ST)}$ = stall speed. It is generally accepted that (Reference 2)

$$V_{(FA)} = 1.3 \ V_{(ST)}$$

$$\text{and } V_{(MA)} = 1.5 \ V_{(ST)}$$

$$\text{therefore, } V_{(MA)} = 1.15 \ V_{(FA)} \qquad (1)$$

Furthermore, it is assumed that aircraft fly at constant $V_{(MA)}$ and $V_{(FA)}$ speeds.

Figure 7 depicts aircraft 1 at its gate and aircraft 2 at its MAP. On the basis of the procedure's description given before, these fixes determine the minimum separation of two converging aircraft during final approach: when aircraft 2 is at its MAP, aircraft 1 should be at a point no further than its gate.

Assume that both aircraft are about to execute straight-out missed approaches, which is the occurrence of concern because it means that both aircraft are going to reach the intersection. Aircraft 1 will reach it t_1 seconds and aircraft 2 t_2 seconds after the moment depicted in Figure 7. One of the procedure's stated objectives is to make sure that the two aircraft pass the intersection at different times. The time difference (or time separation), Δt, is to provide adequate separation assurance. The time difference is,

$$\Delta t = t_1 - t_2 \qquad (2)$$

Aircraft 2 will fly at a speed $V_{2(MA)}$ from its MAP to the intersection. This will take a time,

$$t_2 = \frac{2900 + R_2}{V_{2(MA)}} \qquad (3)$$

At the same time, as aircraft 2 is flying from its MAP to the intersection, aircraft 1 will be flying from its gate to the intersection, initially at a speed $V_{1(FA)}$ and, once it passes its MAP, at a speed $V_{1(MA)}$.

That will take a time,

$$t_1 = \frac{G_1 - 2900}{V_{1(FA)}} + \frac{2900 + R_1}{V_{1(MA)}} \tag{4}$$

Substituting (3) and (4) in (2):

$$\Delta t = \frac{G_1 - 2900}{V_{1(FA)}} + \frac{2900 + R_1}{V_{1(MA)}} - \frac{2900 + R_2}{V_{2(MA)}} \tag{5}$$

Simplifying (5) and solving it for G_1:

$$G_1 = V_{1(FA)}\left[\frac{R_2 + 2900}{V_{2(MA)}} - \frac{R_1 + 2900}{V_{1(MA)}} + \Delta t\right] + 2900 \tag{6}$$

Now, using (1) for aircraft 1 and 2:

$$V_{1(MA)} = 1.15\ V_{1(FA)} \tag{7}$$

$$V_{2(MA)} = 1.15\ V_{2(FA)} \tag{8}$$

Substituting (7) and (8) in (6):

$$G_1 = V_{1(FA)}\left[\frac{R_2 + 2900}{1.15\ V_{2(FA)}} - \frac{R_1 + 2900}{1.15\ V_{1(FA)}} + \Delta t\right] + 2900 \tag{9}$$

Equation 9 shows, for approach 1, the distance from the gate to the runway threshold. Notice that the gate's location is a function of runway geometry (R_1 and R_2), aircraft final approach speeds ($V_{1(FA)}$ and $V_{2(FA)}$), and the required time separation at the intersection (Δt). Of these three elements, only one, time separation, can be established and controlled by the air traffic control system. The runways' geometry is, of course, fixed. The aircraft speeds depend on aircraft size and pilots' decisions. Clearly, the gate's location is variable and for any given fixed time separation, its location will depend on the speed of the approaching aircraft.

3.3.1.2.2 **Visual Aids.** In order to help radar controllers maintain the stagger between approaching aircraft, it is important to provide them with automated visual aids. Mundra (Reference 4) has proposed a controller aid that provides computer-driven visual clues on the radar screen. The aid would be incorporated into the display of Automated Radar Terminal Systems (ARTS) of the Terminal Radar Approach Control Facilities (TRACONs) and simultaneously shown on the BRITE displays of airport towers.

Based on the known fact that controllers normally handle IFR dependent parallel approaches successfully, the idea is to make converging approaches appear on the radar screens as parallel approaches. Figure 8 (adapted from Reference 4) shows converging approaches A and B. A computer shows a "mirrored" approach A that runs parallel to approach B. The mirrored approach is created ensuring that the stagger between aircraft on approaches A and B will be the same as the stagger between the mirrored approach and approach B. This way, controllers will be conducting dependent approaches to converging runways in the manner they do it when they conduct dependent approaches to parallel runways.

There are three possible ways to determine the position of the gate shown on the radar display by the visual aid:

The first and most elaborate case occurs when a computer assigns a time separation (Δt) depending on the approaching aircraft types and sizes. There is a different Δt for each pair of aircraft types. Using a variable Δt and the anticipated aircraft speeds, the computer determines the gate location, which will change with each arrival.

The second way of handling the arrivals is by fixing the time separation (Δt) to a single value that provides adequate separation assurance and wake vortex protection for all pairs of aircraft. The computer then determines the gate location using a fixed Δt and variable aircraft speeds. The gate's position fluctuates less and is more predictable than when using the method of the past paragraph.

The third and simplest method of operation occurs when, regardless of approaching aircraft types or speeds, the gate location is permanently fixed. This can be done by placing the gate's fix at a location that takes into account aircraft pairs flying at speeds that require the longest stagger at the airport in question. Fixing the gate's location facilitates the implementation of the visual aid as well as the controllers' workload. However, it also means in effect to allow a time separation which may be longer or shorter than the one providing largest capacity.

3.3.2 Conditional Mode

3.3.2.1 Distance Stagger. Figure 9 depicts the geometrical characteristics of the conditional mode proposed by Mundra (Reference 4). Just as in Figure 6, two aircraft are shown here, one leading and one trailing. And just as in the non-conditional case, the main objective is to provide adequate separation if aircraft on both approaches execute consecutive missed approaches. The non-conditional mode uses time as a basis to ensure separation on intersecting paths. The conditional mode, on

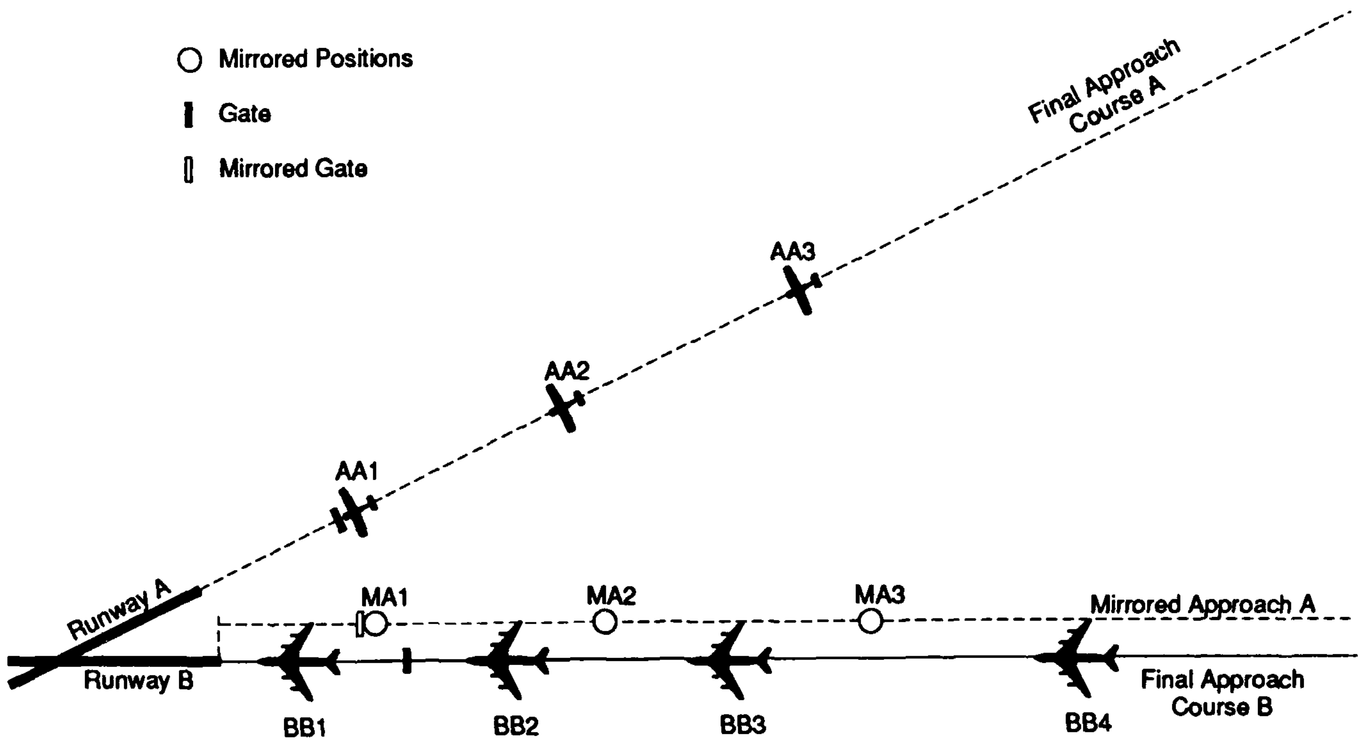


FIGURE 8
PROPOSED VISUAL AID FOR IFR APPROACHES TO CONVERGING RUNWAYS

the other hand, prevents the paths from intersecting altogether through the execution of turning missed approaches, as shown in Figure 9. To ensure that the turning paths do not overlap, the leading and trailing aircraft are staggered. The stagger is calculated so the turning TERPS obstacle surfaces do not overlap (for detailed information on TERPS surfaces, see Reference 5). Aircraft are assumed to stay within the boundaries of their corresponding TERPS surface. This ensures that their missed approach paths do not cross. The following paragraphs explain how an adequate stagger is determined.

3.3.2.2 Breakaway Point. The following method is used for finding the breakaway point on any of the two converging approaches: a MAP is established on one approach (normally corresponding to a 200-foot decision height) while a breakaway point is determined for the other approach. The breakaway point is placed as close as possible to its corresponding threshold such that the turning TERPS surfaces, beginning at each of these points (MAP on one approach and breakaway point on the other approach), do not overlap (see Figure 9). The same method is used to determine the location of the breakaway point on the other converging approach. The controller is to ensure that two aircraft (each on a different approach) are never allowed to be present simultaneously between their breakaway point and MAP. If the leading aircraft initiates a missed approach, the controller is required to order the trailing aircraft on the other approach to go-around at or before its breakaway point.

The criterion to define the geometry of the TERPS surfaces is based on FAA standards, as published in Reference 5. Those standards assume a 90-degree (or greater) turn and use only the primary obstacle clearance surface.

Some assumptions, similar to the ones applied to non-conditional approaches, were considered (see Section 3.3.1.2.1): a 3-degree final approach slope; and both MAPs at the same altitude (unless special restrictions apply). Additionally, the TERPS surfaces geometry is based on a 3.5-nmi turning boundary radius (obstacle clearance radius), which corresponds to a one-fourth standard rate turn for approach category D aircraft.

A few additional points are worth mentioning:

- Intersecting runways are allowed, just as in the non-conditional mode.

- Since a missed approach by one aircraft forces a go-around on the other approach, a disruption of traffic flow occurs on both approaches with consequent delays and increased controller workload.

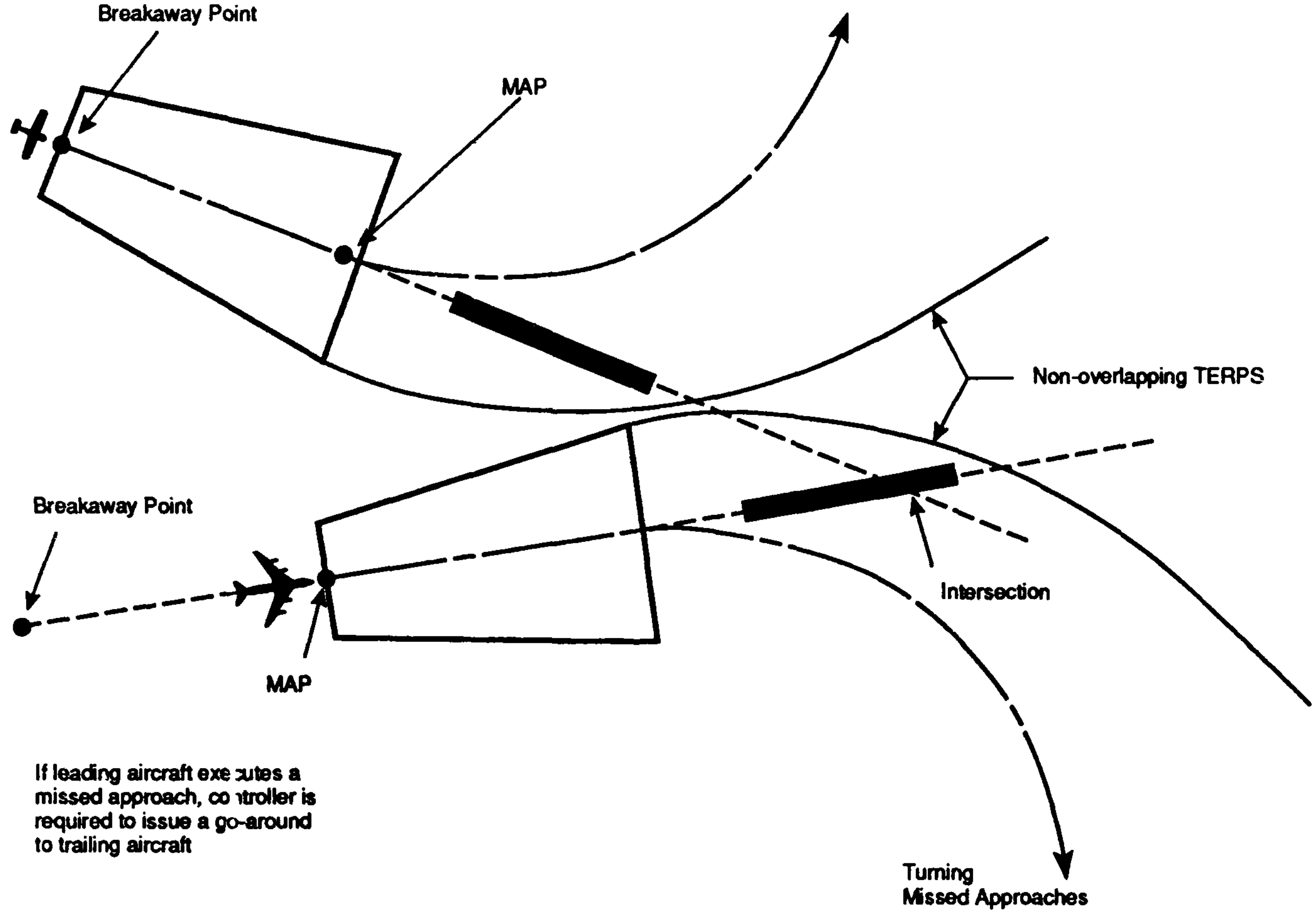


FIGURE 9
CONDITIONAL DEPENDENT IFR APPROACHESTO CONVERGING RUNWAYS

- If, for any reason, the trailing aircraft arrives at its breakaway point before the leading aircraft gets to its MAP, the controller is required to issue a go-around to the trailing aircraft.

3.3.2.3 Visual Aids. Unlike the non-conditional mode, in the case of conditional approaches, the location of the breakaway point is determined by the fixed location of the MAPs and does not depend on the speed of approaching aircraft. Therefore, the breakaway point is not a movable fix (as gates can sometimes be). Automated visual aids can help controllers maintain the stagger between aircraft.

The following sections (Section 4) discuss the potential benefits and limitations of dependent approaches to converging runways.

4.0 POTENTIAL BENEFITS AND LIMITATIONS

The following sections deal with the general issue of arrival capacity in an IFR converging approach environment. That is followed by a discussion on the benefits derived from implementing IFR dependent approaches to converging runways at a number of airports.

4.1 IFR Arrival Capacity Vis-A-Vis Runway Configuration

Multiple IFR arrival stream capacity is highly dependent on runway configuration. Within multiple stream configurations, a dependent converging approach configuration usually is not the one that yields most capacity. Yet, it is often the only feasible configuration for a variety of reasons. Thus, it is important to have some perspective of where converging approaches fit in the general scheme of dual stream approach capacity (for more details on this subject, see Reference 6).

Whenever runway geometry and weather allow it, the preferred type of approach procedures are independent converging approaches (such as TERPS+3). As mentioned before, independent approaches to converging runways yield about 54 arrivals per hour.

If independent converging approaches are not feasible for the reasons mentioned above, independent parallel approaches are then the preferred type of approaches. Since its two streams are independent of each other, these procedures also double the arrival capacity of a single-runway approach to about 54 arrivals per hour. Independent parallel approaches require two extra monitor controllers and increased traffic coordination at the point where the two streams join their final approach courses at different altitudes. That is why independent converging operations are preferred, even though both procedures yield the same capacity.

When independent parallel approaches cannot be used, in most cases (depending on the precise runway geometry), dependent parallel approaches yield the largest possible arrival capacity (about 35 arrivals per hour). There are some instances however, as will be shown later, in which dependent converging approaches yield more than 35 arrivals per hour.

In general, dependent converging approaches are a last-choice multiple-stream, IFR procedure. Yet, it is a better choice in many cases than the operation of a single-stream approach. The rest of this report focuses on the benefits of dependent approaches to converging runways.

4.2 Impact of In-Trail Separation on Arrival Capacity

To understand the capacity issues and limitations affecting the dependent converging approach procedure (both modes) described in Section 3, it

is necessary to analyze the effect of the gate-to-MAP distance upon aircraft in-trail separation and then see what is the impact of this in-trail separation over arrival capacity. The conceptual discussion is the same whether it refers to gate-to-MAP or to breakaway-to-MAP distances (non-conditional and conditional mode, respectively). The gate/breakaway fix will be referred to here as "the gate".

4.2.1 Aircraft Stagger

The fact that the procedure does not allow an aircraft to reach its gate if the preceding aircraft on the opposite approach is between its gate and MAP, automatically forces a stagger between the two aircraft. That stagger or buffer may be shorter or longer depending on a variety of variables mentioned in Section 3, but it is always present.

4.2.2 In-Trail Separation

The arrival rate at each of the two converging runways is determined by the in-trail separation between successive aircraft on each approach. The stagger mentioned in the past section, forces an in-trail separation between aircraft within each approach; the shorter the stagger, the shorter the induced in-trail separation. The next few paragraphs explain the relationship between the stagger and the in-trail separation.

Assuming for a moment that all aircraft are flying at the same speed, it is geometrically evident that the in-trail separation on one approach is at least twice the gate-to-MAP distance on the opposite approach (Figure 10). Notice that aircraft (A) has just reached its MAP. Therefore, aircraft (B) has just been cleared to pass its gate. If the distance from that gate to the MAP is say, 2 nmi, aircraft (C) on the other approach should be at a point at least 2 nmi away from its gate in order to ensure that by the time it reaches it, aircraft (B) will have reached its MAP. As a result of this, the distance from aircraft (A) to aircraft (C) is, as Figure 10 illustrates, at least 4 nmi, or twice the gate-to-MAP distance on the other approach.

The previous discussion is a simplified version of actual approaches. The speeds of various aircraft are rarely exactly the same (although are often similar enough to make this an acceptable simplification); and gates are not located on both approaches at the same distance from the MAPs unless the runways' geometry is symmetrical, as in Figure 10. Yet, for illustration purposes, this example shows the impact of gate location (gate-to-MAP distance) on aircraft in-trail separation.

Analysis has shown that in a dependent converging configuration, a gate-to-MAP separation of about 3 nmi or less leads to a capacity exceeding that of a single runway configuration. Conversely, if the gate-to-MAP distance is too long (3 nmi or longer), the in-trail separation on the

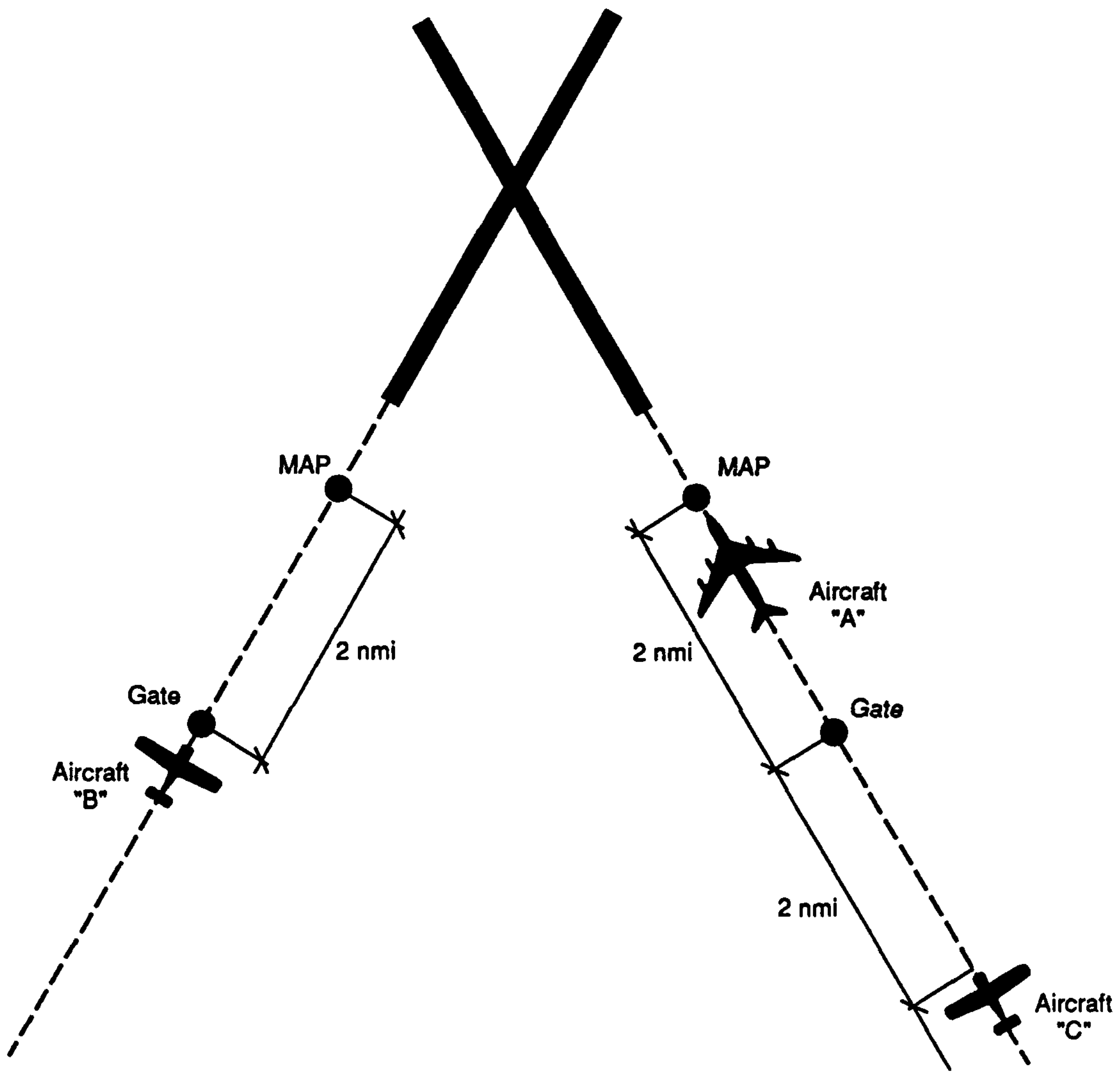


FIGURE 10
IMPACT OF GATE-TO-MAP DISTANCE ON IN-TRAIL SEPARATION

opposite approach may become long enough as to make a single arrival stream (with shorter in-trail separations) preferable to two converging streams. The following section elaborates on this.

4.2.3 Arrival Capacity

The arrival capacity of converging runways can be estimated using the FAA Airfield Capacity Model (see Reference 7). The capacity model has been used extensively, among other things, to estimate the arrival capacity of dependent parallel approaches. This type of approach requires aircraft to keep a stagger by means of a minimum (diagonal) distance between successive aircraft across the two approaches. This aircraft stagger causes an in-trail separation between aircraft on the same approach.

Dependent approaches to converging runways, as explained in Section 4.2.2, require a procedure that (through the use of gates) results in a minimum in-trail separation between aircraft on the same approach. Since this is analogous to dependent parallel approaches, the above-mentioned capacity model can be used to estimate dependent approaches to converging runways. Appendix A shows how the diagonal distance of dependent parallel approaches is used to estimate capacity for dependent approaches to converging runways.

Table 1 shows the hourly arrival capacity* estimated by the Capacity Model for varying gate-to-MAP distances. The assumptions described in Section 4.2.2 and in Appendix A were used. A number of additional assumptions are given below the table.

Notice that as the gate-(or breakaway)-to-MAP distance increases, the number of arrivals per hour decreases. When that distance exceeds 3 nmi (approximately), the capacity gain over a single-runway configuration ceases to exist. Beyond that distance, using a converging configuration is detrimental and a single runway yields larger arrival capacity.

4.3 Impact of Time Separation On Arrival Capacity

As explained in Section 3, stagger and minimum in-trail separation are fixed (at each airport) in the case of the conditional mode. Therefore, capacity can be calculated directly using the information contained in Table 1.

*These figures reflect a typical aircraft mix in some medium- and large-size U.S. airports. The mix derives from standards used in Reference 6.

TABLE 1

EFFECT OF GATE-TO-MAP DISTANCE
UPON CAPACITY GAIN

GATE-TO-MAP DISTANCE (NMI)	ARRIVALS PER HOUR*	CAPACITY GAIN OVER SINGLE RUNWAY
1.0	47	+74%
1.5	42	+56%
2.0	37	+37%
2.5	32	+19%
3.0	29	+ 7%
- - - - - - -	- - - - - - -	- - - - - - -
3.5	26	- 4%
4.0	24	-11%
4.5	22	-19%
5.0	20	-26%
5.5	18	-33%
6.0	17	-37%

*FAA Airfield Capacity Model:

	AIRCRAFT TYPE A	B	C	D
Aircraft Mix (pct)	15	20	55	10
Final Approach Speed (kt)	100	120	130	140
Average Runway Occupancy Time (sec)	40	45	50	55

Single-Runway Capacity: 27 Arrivals Per Hour

In the case of the non-conditional mode, at any given airport, for each given set of time separation and approaching aircraft speeds, the gate will be at a specific distance from the MAP. That distance will determine the configuration's arrival capacity, as shown in Table 1. A shorter time separation produces a shorter stagger. That in turn, leads to a larger arrival capacity.

The question of what time separation to use relates to two different objectives: separation assurance and wake vortex avoidance.

As long as converging aircraft arrive at the intersection at sufficiently different times, separation assurance is achieved. Only in the case of two successive aircraft executing missed approaches is the time separation put to use. The currently used 2-nmi separation at the threshold between departures and arrivals on a single runway suggests that 50 to 60 seconds (i.e., 2 nmi at a speed of about 120 kt) is an acceptable amount of time separation in the runway area.

Wake vortex separation is a more complex matter. Wake vortices generated by heavy aircraft can be hazardous for lighter aircraft. The hazard depends on the strength of the turbulence and the rate at which the airmass returns to a safe situation. For that reason, the FAA requires minimum in-trail separations for various aircraft pairs, depending on their size. These required in-trail separations vary from 2.5 to 6 nmi (see Reference 8 for more details).

Despite the fact that the above-mentioned in-trail standards have been in use for many years, there is some question about their conclusiveness. While these standards are undoubtedly safe, there is some indication that shorter in-trail separations may remain safe. For instance, although there is a requirement of at least a 2.5-nmi longitudinal separation on final approach in IFR, observation of VFR separations has shown the feasibility of reduced longitudinal separation (down to 2 nmi) for some aircraft pairs. An in-trail separation of 2 to 3 nmi translates into time separations of 60 to 90 seconds for aircraft flying at about 120 kt.

It is beyond the scope of this report to investigate the minimum safe wake vortex time separations for all aircraft pairs. Based on the discussion above, it is assumed that for many (albeit not all) aircraft pairs, a time separation of 50 to 90 seconds may provide adequate separation assurance and wake vortex avoidance. A parametric analysis as well as an airports benefit table presented in the following sections use time separations within the above-mentioned range.

4.4 A Parametric Analysis of the Gate Location as a Function of Runway Configuration (Non-Conditional Mode)

The location of gates in the non-conditional mode is a function of several variables. Two of those variables, R_1 and R_2, lump together the geometric characteristics of any given configuration, as Section 3.3.1.2.1 and Equation 9 show. Therefore, to gain some insight on the impact of various runway configurations upon gate location, it is useful to examine Equation 9 (G_1 is the gate-to-threshold distance on approach 1, as shown in Figure 7).

From Section 3.3.1.2.1

$$G_1 = V_{1(FA)} \left[\frac{R_2 + 2900}{1.15\ V_{2(FA)}} - \frac{R_1 + 2900}{1.15\ V_{1(FA)}} + \Delta t\right] + 2900 \qquad (9)$$

(9) can be rearranged as

$$G_1 = \frac{V_{1(FA)}}{V_{2(FA)}} \left[\frac{R_2}{1.15} + 2522\right] + V_{1(FA)}\ \Delta t - \frac{R_1}{1.15} + 378 \qquad (10)$$

Equation 10 shows that, given a configuration and a separation time, the one factor affecting the location of the gate is the speed of the approaching aircraft. The relative speeds between successive aircraft, portrayed as the ratio

$$\frac{V_{1(FA)}}{V_{2(FA)}}$$

is of particular importance, as intuition may suggest.

Figure 11 shows a family of curves representing the values of G_1 for various configurations (G_1 as a function of R_1 and R_2) and constant speeds and time separation.

To obtain Figure 11, Equation 10 is solved for R_1

$$R_1 = \frac{V_{1(FA)}}{V_{2(FA)}} R_2 + 1.15 \left[\frac{2522\ V_{1(FA)}}{V_{2(FA)}} + V_{1(FA)}\ \Delta t - G_1 + 378\right] \qquad (11)$$

Figure 11 shows the family of gate locations (values of G_1) for aircraft approaching at speeds $V_{1(FA)} = 140$ kt, $V_{2(FA)} = 120$ kt, and a time separation $\Delta t = 60$ sec. The upper straight line represents configurations for which $G_1 = 0$, i.e., if the gate is placed at the runway threshold. Notice that the (R_1, R_2) pairs for which $G_1 = 0$, are unlikely to occur.

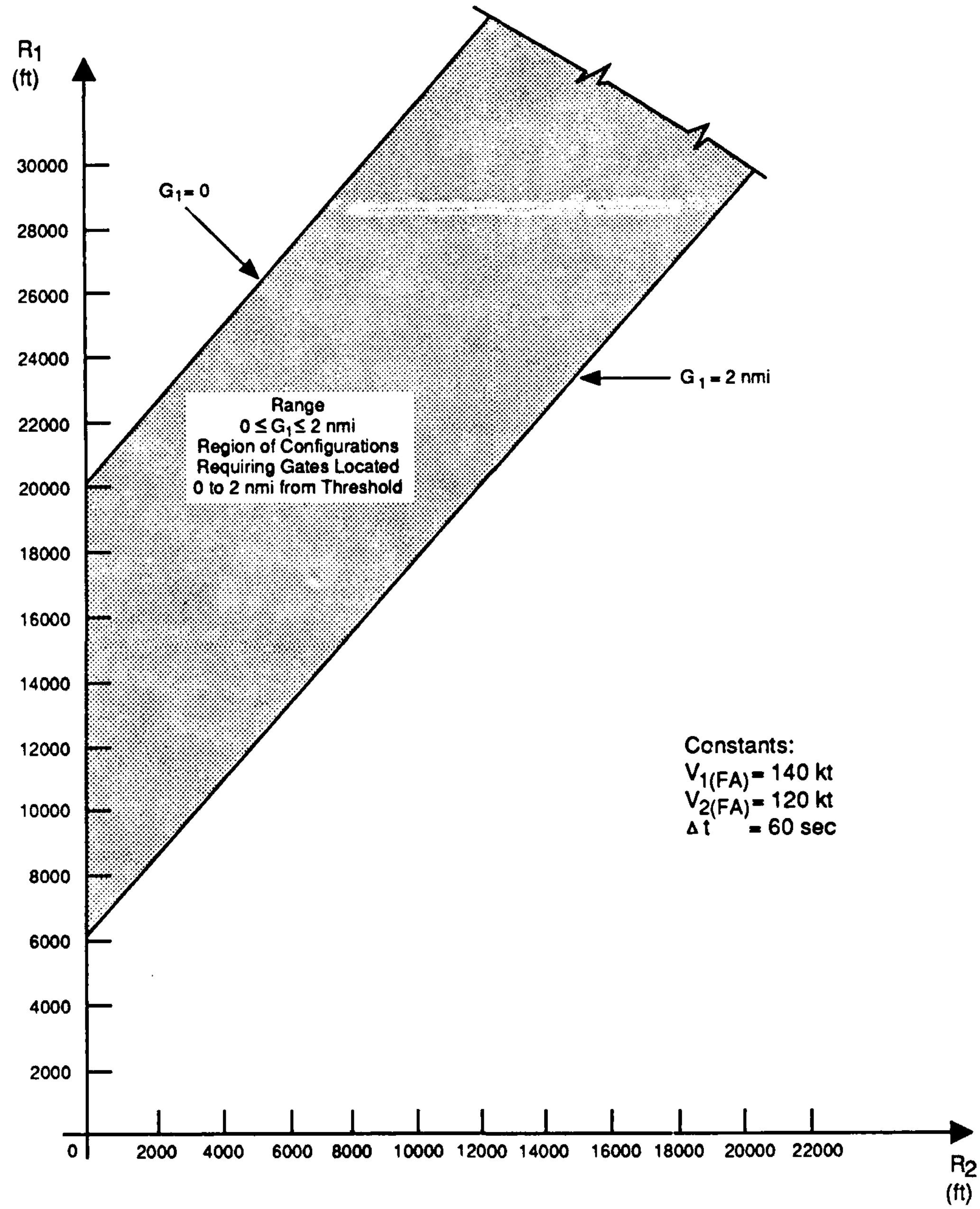


FIGURE 11
GATE-TO-THRESHOLD DISTANCE (G_1) AS A FUNCTION OF RUNWAY CONFIGURATION (R_1, R_2)

The shaded area under the $G_1 = 0$ line represent (R_1, R_2) pairs for which $0<G_1<2$ nmi. G_1 lines are always parallel among themselves for each G_1 family (i.e., for each set of $V_{1(FA)}$, $V_{2(FA)}$, Δt). The line representing $G_1 = 2$ nmi shows realistic configurations that require a gate located 2 nmi from the threshold. For instance, this includes a configuration consisting of two intersecting runways, one 13,000 feet and the other 6,000 feet-long from their threshold to their intersection point. Notice that as the value of G_1 increases (lines intersecting the R_1 axis at points lower than 6,000 feet), more commonplace configurations are allowed. Yet, a high G_1 is undesirable from a capacity standpoint.

Families of gate locations for varying speeds and time separations can be drawn to help the analyst determine whether a given configuration can use gates that allow capacity increases.

4.5 Benefit Analysis

Section 4.1 described several alternatives for conducting multiple-stream IFR approaches. Dependent approaches to converging runways usually provide lower arrival capacity than any of them.

Nevertheless, airports may need dependent converging approach procedures for either of the following reasons:

- The airport has no parallel or converging runways that can be used simultaneously due to geometric factors or to ceilings lower than those required by the TERPS+3 procedure (see four airports above dark line in Table 2).

- The airport has parallel runways that can be used simultaneously. However, special circumstances (wind shifts, runway closings, snow removal, etc.), may occasionally prevent the use of a runway. On those occasions, converging approaches may yield higher arrival capacity than the other alternative, namely, single-runway approaches (see thirteen airports under dark line in Table 2).

Table 2 illustrates the tradeoffs between TERPS+3 and dependent approach procedures to converging runways (both non-conditional and conditional) for selected U.S. airports. A somewhat restrictive airport inclusion criteria was used, as follows:

- Airports with at least three runways, including a non-intersecting departure runway.

AIRPORT	RUNWAYS ARRIVALS (RWY 1/ RWY 2)	RUNWAYS DEPAR-TURES	RWYS 1 and 2 Angle	TERPS +3 DH	Avg. Daily Time (min) Under 1500'/400'	DEPENDENT (ALTERNATING) APPROACHES TO CO: DH	CONDITIONAL (Breakaway-type) APPROACHES: DH Improve-ment Over TERPS+3	CONDITIONAL (Breakaway-type) APPROACHES: Brkwy-MAP Distance (nmi)	CONDITIONAL (Breakaway-type) APPROACHES: Arrivals Per Hour	CONDITIONAL (Breakaway-type) APPROACHES: Capacity Improv. Over Single Rwy: Additional Hrly Capacity (% Improv.)	Time Separa-tion
Anchorage (ANC)	14/6L	6R	75°	733'	66/12	200'	533'	3.3	27	0(0%)	60 sec 80 sec
Boston[1] (BOS)	22L/27	22R	57°	772'	146/23	443'	329'	1.8	39	12(44%)	60 sec
Denver (DEN)	17L/26L	26R	87°	411'	60/9	200'	211'	1.7	40	13(48%)	60 sec
St. Louis[2] (STL)	24/30L	30R	59°	754'	103/13	250'	504'	2.8	30	3(11%)	60 sec 80 sec
Chicago (ORD)	22R/27L	22L	51°	488'	146/17	200'	288'	1.4	43	16(59%)	60 sec
Dallas[3] (DFW)	31R/35R	35L	45°	646'	81/8[5]	200'	446'	1.6	41	14(52%)	60 sec
Dayton (DAY)	18/24L	24R	57°	858'	143/18	200'	658'	3.2	28	1(4%)	60 sec 80 sec
Detroit (DTW)	21R/27	21L	60°	736'	124/17	200'	536'	2.8	30	3(11%)	60 sec 80 sec
Dulles (IAD)	12/19R 12/19L	19L 19R	70° 70°	515' 401'	102/22	200' 200'	315' 201'	1.9 1.3	38 44	11(41%) 17(63%)	60 sec 60 sec
Honolulu (HNL)	22L/26L	26R	36°	975'	5/0	200'	775'	2.1	36	9(33%)	60 sec
Memphis (MEM)	27/36R	36L	87°	721'	86/9	200'	521'	3.0	29	2(7%)	60 sec 80 sec
Miami[4] (MIA)	27R/30	27L	30°	>1000'	21/3	200'	> 800'	2.3	> 34	7(26%)	60 sec 80 sec
New York (JFK)	13L/22L	22R	90°	848'	134/21	200'	648'	3.9	24	-3(-11%)	60 sec 80 sec
Oklahoma (OKC)	12/17R	17L	45°	>1000'	87/13	200'	> 800'	3.1	28	1(4%)	60 sec 80 sec
Pittsburgh (PIT)	10R/32	10L	135°	960'	155/17	200'	760'	4.7	22	-5(-19%)	60 sec 80 sec
Portland (PDX)	10R/2	10L	74°	902'	85/13	200'	702'	3.5	26	-1(-4%)	60 sec 80 sec
Tampa (TPA)	18L/27	18R	90°	868'	55/10	200'	668'	> 5.7	< 18	< -9(-33%)	60 sec 80 sec

NOTE: A somewhat restrictive airport inclusion criteria was used to prepare this table. Therefore, the airports, Decision Heights and associated capacities shown here, should not be construed as a best alternative. For a complete discussion on this table, see Sections 4.5 and 4.6.

[1] Published Category I Decision Heights are 404' (Rwy 22L) and 443' (Rwy 27).
[2] Published Category I Decision Heights are 250' (Rwy 24) and 200' (Rwy 30L).
[3] Has configurations that allow independent approaches to converging runways (TERPS+3) down to a 200' Decision Height.
[4] Currently, no ILS on Rwy 30.
[5] Love Field Airport ceilings.

DEPENDENT (ALTERNATING) APPROACHES TO CONVERGING RUNWAYS								
		CONDITIONAL (Breakaway-type) APPROACHES			NON-CONDITIONAL APPROACHES			
[illegible]H	DH Improvement Over TERPS+3	Brkwy-MAP Distance (nmi)	Arrivals Per Hour	Capacity Improv. Over Single Rwy: Additional Hrly Capacity (% Improv.)	Time Separation	Gate-Thresh. Distance (nmi)	Arrivals Per Hour	Capacity Improv. Over Single Rwy: Additional Hrly Capacity (% Improv.)
[illegible]0'	533'	3.3	27	0(0%)	60 sec 80 sec	1.9 2.6	38 32	11(41%) 5(19%)
[illegible]3'	329'	1.8	39	12(44%)	60 sec	1.9	38	11(41%)
[illegible]0'	211'	1.7	40	13(48%)	60 sec	1.8	39	12(44%)
[illegible]0'	504'	2.8	30	3(11%)	60 sec 80 sec	1.9 2.6	38 32	11(41%) 5(19%)
[illegible]0'	288'	1.4	43	16(59%)	60 sec	1.8	39	12(44%)
[illegible]0'	446'	1.6	41	14(52%)	60 sec	1.8	39	12(44%)
[illegible]0'	658'	3.2	28	1(4%)	60 sec 80 sec	2.0 2.6	37 32	10(37%) 5(19%)
[illegible]0'	536'	2.8	30	3(11%)	60 sec 80 sec	1.9 2.6	38 32	11(41%) 5(19%)
[illegible]0' [illegible]0'	315' 201'	1.9 1.3	38 44	11(41%) 17(63%)	60 sec 60 sec	1.8 1.8	39 39	12(44%) 12(44%)
[illegible]0'	775'	2.1	36	9(33%)	60 sec	1.8	39	12(44%)
[illegible]0'	521'	3.0	29	2(7%)	60 sec 80 sec	1.9 2.6	38 32	11(41%) 5(19%)
[illegible]0'	> 800'	2.3	> 34	7(26%)	60 sec 80 sec	1.9 2.5	38 32	11(41%) 5(19%)
[illegible]0'	648'	3.9	24	-3(-11%)	60 sec 80 sec	2.0 2.6	37 32	10(37%) 5(19%)
[illegible]'	> 800'	3.1	28	1(4%)	60 sec 80 sec	2.0 2.6	37 32	10(37%) 5(19%)
[illegible]'	760'	4.7	22	-5(-19%)	60 sec 80 sec	1.9 2.6	38 32	11(41%) 5(19%)
[illegible]'	702'	3.5	26	-1(-4%)	60 sec 80 sec	2.0 2.7	37 31	10(37%) 4(15%)
[illegible]'	668'	> 5.7	< 18	< -9(-33%)	60 sec 80 sec	2.0 2.6	37 32	10(37%) 5(19%)

[illegible] prepare this table. Therefore, the airports, [illegible] not be construed as a best alternative. For a

[illegible]y 27).
[illegible] 30L).
[illegible]ways (TERPS+3) down to a

TABLE 2
A COMPARISON BETWEEN
THE TERPS+3 PROCEDURE
AND DEPENDENT IFR APPROACHES
TO CONVERGING RUNWAYS

The procedures presented in Section 3 are for arrivals only. A runway has to be reserved for departures alone. The departing aircraft should not conflict with the arrivals, this being the reason for requiring a non-intersecting departure runway.

- Each runway is 7,000 feet or longer.

  This is to include only runways that can handle a wide variety of aircraft sizes.

- With the exception of Washington Dulles, only one converging configuration was chosen for each airport. It is not necessarily the one yielding the highest capacity at that airport.

Single-runway capacity is the best current Category I configuration applicable to the first four airports shown in Table 2. The other airports can use configurations that provide larger capacity than dependent converging approaches. Therefore, the latter procedure would be of use only in special circumstances, such as wind shifts and runway closings. The table (and the assumptions made) can best be explained by using an example. Let us use Memphis (MEM).

A comparison between three arrival procedures is made: TERPS+3, conditional, and non-conditional approaches to converging runways. In the case of Memphis, runways 27 and 36R are considered for converging arrivals. Runway 36L is reserved for departures alone. The included angle of 27 and 36R is 87 degrees. The geometrical information (angles and runway lengths) were estimated from airport layout diagrams.

A computer program developed by MITRE (Reference 3) was used to calculate Memphis' TERPS+3 DH. The resulting DH is 721 feet. That means that whenever the ceiling is above 800 feet (ceilings are reported in 100-foot increments), the TERPS+3 procedure can be used to land converging aircraft, and arrival capacity can be as high as 54 arrivals per hour (the approximate capacity of independent approaches to converging runways).

If the ceiling in Memphis is under 800 feet, other approach procedures have to be used. In Memphis, that includes the use of a parallel configuration at any time during IFR operations. Yet, if runway closings leave open only the possibility of a converging configuration and the ceiling is lower than 800 feet, dependent converging approaches are the only solution. A rough idea of the length of time during which low ceilings occur is given in the table by the average daily time (in minutes) during which ceilings are between 400 and 1500 feet and between 200 and 400 feet (in the table, this is under the shortened heading "under 1500 feet/400 feet"). Reference 9 was used to estimate the above-mentioned

figures (for 16-hour days). In Memphis' case, the average daily time with ceilings under 1500 feet is 86 minutes while the figure for low ceilings (200 to 400 feet) is 9 minutes. Naturally, weather statistics are not uniformly distributed and an average 9 minutes per day can easily mean that there are days during which low ceilings prevail, on and off, throughout the day. These figures are given for comparison among airports.

Table 2 capacity analysis for dependent approaches to converging runways uses a 200-foot DH (Category I minimum DH) unless the airport in question does not allow such minimum (as in Boston and St. Louis)[1]. Memphis allows a 200-foot DH, as Table 2 shows. Equally shown is the DH improvement over TERPS+3, which for Memphis is 721 minus 200 = 521 feet. That is, dependent approaches to converging runways can be operated in Memphis with cloud bases as much as 521 feet lower than the lowest allowed by TERPS+3.

The arrival capacities for the conditional and non-conditional modes are shown. A modified version of the computer program of Reference 3 was used to estimate the breakaway-to-MAP distance. Using the highest breakaway point of the two converging approaches (symmetrical runways have symmetrical breakaway points), the arrival capacity was estimated using the results of Table 1. Memphis, with a breakaway-to-MAP distance of 3 nmi, can yield 29 arrivals per hour. If one considers a single-runway IFR capacity of 27 arrivals per hour (a value that varies slightly from airport to airport), then as the table shows, use of the conditional mode in Memphis leads to a capacity improvement over single-runway configuration of two arrivals per hour (or 7 percent).

The estimation of capacity for the non-conditional mode used a similar method. A time separation of 60 seconds was selected for all airports (within the 50 to 90 second range discussed earlier). If the capacity improvement (over single-runway configuration) using the conditional mode was less than 30 percent, then two time separations were used to estimate capacity under the non-conditional mode: 60 and 80 seconds (it was assumed that it was worth it to explore capacity under larger time separations if the conditional mode was not yielding very large capacity improvements). Furthermore, instead of estimating gate-to-MAP distances, a modified version of Equation 9 was used[2] to estimate gate-to-threshold distances.

---

[1] See Section 4.6

[2] $$G_1 = V_{1(FA)} \left[\frac{R_2}{1.15\ V_{2(FA)}} - \frac{R_1 + 2900}{1.15\ V_{1(FA)}} + \Delta t \right] + 2900$$

This modification assumes that some aircraft may initiate missed approaches passed their MAP. Aircraft speeds of 120 and 140 kt were used, each for a different approach. The average gate-to-threshold distance for both approaches is shown in the table. The results for Memphis are 1.9 nmi and 2.6 nmi for time separations of 60 and 80 seconds, respectively. Once again, using Table 1, capacity for the above distances is shown as 38 and 32 arrivals per hour, which reflect improvements over single-runway capacity of 41 and 19 percent. Clearly, the non-conditional mode in Memphis yields more arrival capacity than the conditional mode even when using relatively long time separations, such as 80 seconds.

Examination of Table 2 leaves no doubt about the need to perform airport-specific analyses to decide whether dependent approaches to converging runways are beneficial to the airport in question. The capacity results, especially in the conditional mode, show great variance. Notice, for example, that at some airports (such as Anchorage and Tampa), the conditional mode of operation yields negligible or even negative capacity improvements over single-runway configuration. On the other hand, there are cases (such as Boston's) where the conditional mode yields more capacity than the non-conditional mode. That is, not only the capacity results are airport-specific, but also the "best" mode of operation is airport-specific.

The previous analysis uses a 200-foot DH. If higher DHs had been used, the capacity results would have been different. Section 4.6 elaborates on this.

4.6 Dependent Approaches Using DHs Higher Than 200 Feet

Some airports require DHs higher than 200 feet for reasons such as runway obstacles. Such airports have their MAPs farther away from the threshold. Analysis has shown that in those cases, the breakaway point on the opposite approach can be moved closer to its threshold. The net result of this is less stagger between aircraft and therefore more capacity. Yet, the price of this capacity increase is a higher DH and therefore less amount of time during which the procedure is applicable.

Yet, airports that rarely have low IFR ceilings may benefit from using DHs higher than 200 feet. Their capacity can be larger without detriment to the available time during which dependent approaches can be used, since they are located in places where relatively high ceilings prevail.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The preceding analysis shows the capacity benefits resulting from the operation of dependent approaches to converging runways. While no procedure can be approved until all the details have been worked out (some of them are mentioned later in this section), this report's results indicate the feasibility of the proposed procedure.

5.1 Accomplished Objectives

The objective of this research was the development of an approach procedure to converging runways that allows Category I minima operations, and provides adequate separation assurance and wake vortex avoidance if simultaneous missed approaches occur on both approach streams.

The objective has been accomplished, albeit not without raising some issues. The separation assurance provided by the procedure is adequate. The wake vortex separation is also adequate when using the conditional mode. When using the non-conditional mode, the wake vortex separation is adequate only if enough time separation is allowed, something that often is in conflict with capacity gains. It remains to be determined how much time separation is needed to ensure wake vortex avoidance for all aircraft pairs.

From the arrival capacity standpoint, the procedure proposed in this report improves IFR arrival capacity at selected airports from 4 to 63 percent, depending on such factors as mode of operation, configuration, and desired time separation at the intersection. A 17-airport benefit analysis summarized in Table 2 gives the reader and idea of the improvements that can be expected. It is shown that improvements are not to be expected at all airports. Some of them exhibit an actual arrival capacity decrease if dependent converging procedures are used.

The new concepts are beneficial at a significant number of major U.S. airports. The 17 airports referred to above were chosen through a somewhat restrictive selection process. Of these 17 airports, Boston (BOS), Denver (DEN), and St. Louis (STL), are prime candidates for the procedure.

5.2 Limitations

As with other new procedures, the gains provided by the one presented here have limitations that require further examination.

First, the procedure (both modes) is recommended only at airports that have at least a third runway to be used solely for departures. Procedures must be developed to ensure adequate separation between departures and arrivals.

Second, if computerized visual aids are to be used (as recommended) to help controllers, they have to be developed first. A decision has to be made in the case of the non-conditional mode, whether fixed or moving gates are going to be used, and as mentioned in Section 5.1, it remains to be determined what is an acceptable time separation at the intersection. A range of 50 to 90 seconds appears to be feasible. If, on the other hand, the conditional mode is used, the visual aids will always indicate a fixed breakaway point. However, in this mode of operation, missed approaches on one approach disrupt traffic on the other approach.

Third, decisionmakers should consider the additional approach charts that may have to be developed depending on the existing missed approach procedures and whether the non-conditional or the conditional mode is to be used. Furthermore, an FAA Order and airport directives have to be prepared. Following the line of thought of Order 7110.98 to implement the TERPS+3 procedure (see Appendix B), a draft Order to implement dependent approaches to converging runways has been prepared and presented in Appendix C. It should be emphasized that it is only a proposal.

5.3 Recommendations

This investigation has laid down the groundwork and cited the main problems concerning the implementation of dependent approaches to converging runways. The developmental stage of this research was conducted with constant participation and feedback from the FAA. This author recommends to go forward to the steps of test and evaluation of the procedure.

These steps should include the following:

1. Final preparation by the FAA of a preliminary Order (similar to the one presented in Appendix C) to define the requisites that airports have to fulfill to request permission to operate dependent approaches to converging runways

2. Field simulation of the procedure at FAA facilities and a selected airport

3. Continued development of visual aids for the controller

4. Coordination with users and industry groups

5. Approval of a final FAA Order based on all of the above

6. Airport-specific studies to implement the procedure

The results of this work suggest that a significant number of airports would benefit from the application of the new procedure. Dependent converging approaches can constitute another aid in the controllers' box of tools used to increase overall airport capacity and to decrease delays.

APPENDIX A
CAPACITY ANALOGY BETWEEN DEPENDENT APPROACHES TO PARALLEL RUNWAYS AND DEPENDENT APPROACHES TO CONVERGING RUNWAYS

Figure 12 shows the geometry of a dependent parallel approach with a 2-nmi diagonal separation. The aircraft shown in the figure are keeping the minimum in-trail separation allowed, which is limited by the minimum diagonal distance allowed.

The FAA Airfield Capacity Model can be used to estimate arrival capacity for a configuration such as the one shown in Figure 12. Given a runway separation (3000 feet in this case) and other variables such as aircraft mix, final approach speeds, and runway occupancy times, the model calculates capacity based on the rate of aircraft arrivals to both runways. That rate increases or decreases depending on the minimum diagonal stagger that aircraft are to maintain. As the figure shows, for any given diagonal separation, there is a corresponding minimum in-trail separation. In this case, a 2-nmi diagonal forces a 3.88-nmi in-trail separation.

In the case of approaches to converging runways, the stagger forced upon aircraft across the two approaches is created by a system of gates (or breakaway points). That stagger creates (as in dependent parallels) an aircraft in-trail separation that is ultimately responsible for the aircraft arrival rate, and therefore capacity.

Hence, the FAA Airfield Capacity Model can be used to estimate dependent converging approach capacity calculating the information needed by the model, as follows. First, the gate-to-MAP or breakaway-to-MAP distance as well as the resulting in-trail separation are calculated in the manner described in Section 3. That in-trail separation can then be easily translated into a dependent parallel approach diagonal separation by solving the resulting triangle shown in Figure 12. That diagonal is input to the Airfield Capacity Model whose output then returns the arrival capacity for the given diagonal.

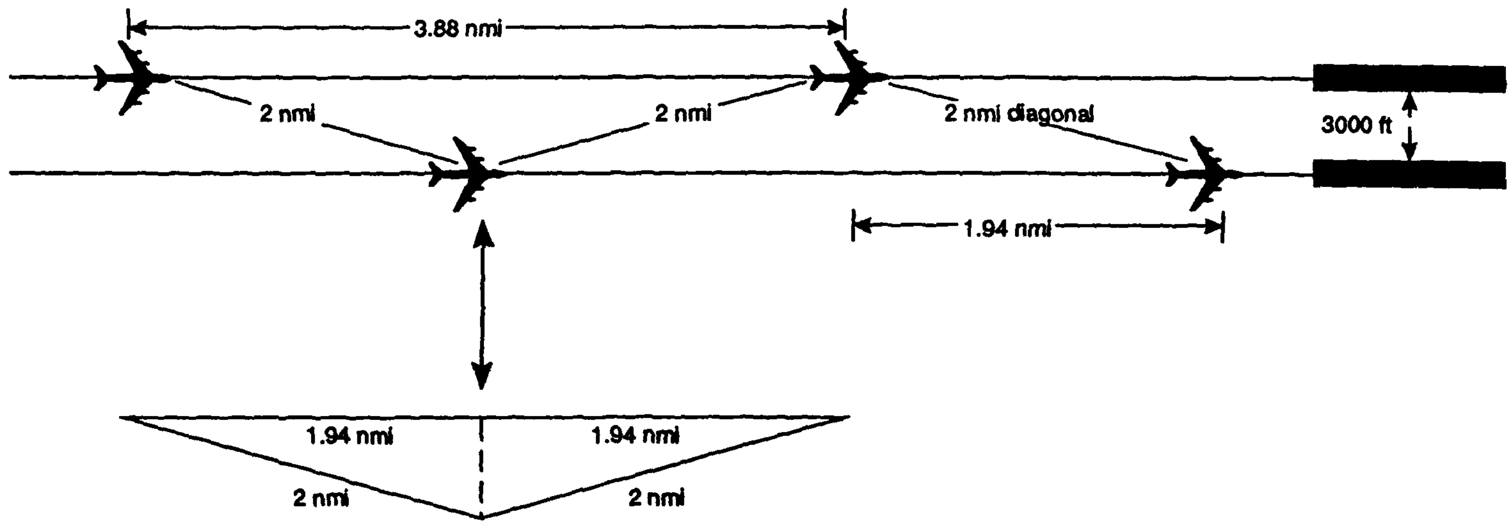


FIGURE 12
A DEPENDENT PARALLEL APPROACH
(2-NMI DIAGONAL)

APPENDIX B
FAA ORDER 7110.98
SIMULTANEOUS CONVERGING INSTRUMENT APPROACHES (SCIA)
("TERPS+3")

ORDER

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

7110.98

ADVANCE COPY

4/3/86

SUBJ: Simultaneous Converging Instrument Approaches (SCIA)

1. PURPOSE. This order defines criteria and establishes procedures for conducting simultaneous instrument approaches to converging runways in instrument weather conditions.

2. DISTRIBUTION. This order is distributed to division level in Washington air traffic offices, branch level in regional air traffic and flight standards offices, the Mike Monroney Aeronautical Center, the Technical Center, and air traffic and flight inspection field offices.

3. BACKGROUND.

a. Instrument approaches have been conducted simultaneously to converging runways during VFR weather conditions at many airports throughout the system for years. A few select locations conduct these operations in IFR weather, but only through the application of visual separation and in accordance with a local facility directive specifying conditions and procedures.

b. Key user group representatives recommended development of national standardized criteria for conducting simultaneous converging approaches in IFR conditions. In response, a proposal was circulated in May of 1983 which drew mixed reviews, including some opposition. A revised proposal was offered May of 1985. Based on comments received and extensive coordination with Flight Standards and user representatives these procedures were developed.

4. DEFINITION. For the purpose of this directive, converging runways are defined as runways having an included angle between 15 and 100 degrees.

5. REFERENCES. Handbooks 7110.65, 7210.3, and FAA Order 8400.9

6. PROGRAM. Simultaneous converging instrument approach procedures will be developed by ATC in accordance with the following:

a. Determine that the volume and complexity of aircraft operations requires the use of simultaneous converging instrument approaches and that no operational hardship on users or control facilities will result.

b. If runways intersect, coordinate with airport management to ensure that runway intersection identification markings are in accordance with appropriate standards.

Distribution: A-W(AT/TO/TR)-2; A-X(AT/FS)-3; A-Y(AY)-2; A-Z(ST)-2; A-FAT-O(LTD); A-FFS-4(LTD); ZAT-423(External) Military (Ltd)

Initiated By: ATO-320

c. Coordinate with the responsible flight inspection field office for feasibility of procedural design and the ability to achieve minimums sufficient to justify procedure development.

d. Prepare a staff study including the following additional items:

(1) Generally, what type aircraft and user groups will be involved.

(2) Anticipated effect on airport/airspace capacity, including projected reductions in delays and fuel consumption.

(3) Daily time periods during which the procedure would most likely be applied.

(4) A preliminary environmental review.

e. Submit proposals to the regional air traffic division for approval and coordination with Flight Standards. Upon completion of this coordination and with regional endorsement, all documents and final drafts pertinent to the program shall be submitted to the Procedures Division, ATO-300, for review, coordination with AFS-200, and authorization prior to implementation.

f. At least 60 days before the effective date, publish a Letter to Airmen defining local procedures to be used. Additional means of publicizing local procedures (pilot meetings, etc.) shall be employed as per Handbook 7210.3, paragraph 423, "Coordination of ATC Procedures."

7. CRITERIA. The requirements for conducting simultaneous instrument approaches to converging runways are:

a. Radar availability.

b. Precision instrument approach systems on each runway.

c. Nonintersecting final approach courses.

d. Separate dedicated Standard Instrument Approach Procedures (SIAP) specifically denoted for converging approach use are developed to each runway.

(1) Missed approach points (MAP) must be at least 3 nautical miles (NM) apart.

(2) Published missed approach procedures diverge and the associated primary TERPS surfaces do not overlap.

e. Runways do not intersect unless visual separation can be applied by the controller. Converging approaches shall not be conducted simultaneously to intersecting runways below a 700-foot ceiling or 2-mile visibility.

NOTE: Although simultaneous approaches may be conducted to intersecting runways when the conditions in this directive are satisfied, staggered approaches may be necessary in order to meet the requirements of FAA Handbook 7110.65, paragraph 3-123, "Intersecting Runway Separation."

f. A facility directive or Letter of Agreement specifying as a minimum:

(1) each applicable runway configuration;

(2) designation of a primary and secondary runway for each configuration, including separation responsibility and procedures to be applied in the event a missed approach is initiated inside the MAP;

(3) coordination requirements; and

(4) weather minima applicable to each configuration if different from published minima.

NOTE: Because of local, site specific considerations, facility management may wish to establish higher minima than published on the SIAP to preclude, to the extent feasible, the possibility of a weather related missed approach.

g. Approach control shall have direct communications capability with the local controller at locations where separation responsibility has not been delegated to the tower.

8. PROCEDURES. You may authorize simultaneous instrument approaches to converging runways under the following conditions.

a. Only straight-in approaches will be made.

b. Navigational aids and appropriate frequencies are operating normally.

c. Aircraft are informed on initial contact or as soon as possible thereafter that simultaneous converging approaches are in use. This information may be provided through ATIS.

d. Weather activity that could impact the final approach courses is closely monitored. If weather trends indicate deteriorating conditions which would make a missed approach probable, discontinue simultaneous converging approach operations.

9. GENERAL.

a. Record any occurrence of simultaneous missed approaches while conducting SCIA on the Daily Record of Facility Operation, Form 7230.4, and submit a brief summary to the Procedures Division, ATO-300, through the appropriate regional air traffic division, within 20 days. Include aircraft ID, type, weather, reason for each of the missed approaches, and any other pertinent data.

APPENDIX C
DRAFT FOR AN FAA ORDER
DEPENDENT CONVERGING INSTRUMENT APPROACHES (DCIA)
(ALTERNATING APPROACHES)

DRAFT FOR AN FAA ORDER
DEPENDENT CONVERGING INSTRUMENT APPROACHES (DCIA)
(ALTERNATING APPROACHES)

1. PURPOSE. This order defines criteria and establishes procedures for conducting dependent instrument approaches to converging runways in instrument weather conditions.

2. DISTRIBUTION. This order is distributed to division level in Washington air traffic offices, branch level in regional air traffic and flight standards offices, the Mike Monroney Aeronautical Center, the Technical Center, and air traffic and flight inspection field offices.

3. BACKGROUND.

    a. Instrument approaches have been conducted simultaneously to converging runways during VFR weather conditions at many airports throughout the system for years. A few select locations conduct these operations in IFR weather, but only through the application of visual separation and in accordance with a local facility directive specifying conditions and procedures.

    b. At least two airports are operating simultaneous approaches to converging runways using the principles established in FAA Order 7110.98 (TERPS+3).

    c. Because many airports cannot use 7110.98 due to the runway layout or they can only use it down to decision heights not much lower than 600 feet, a new procedure was developed to allow dependent operations.

4. DEFINITION. For the purpose of this directive, converging runways are defined as runways having an included angle between 15 and 100 degrees.

5. REFERENCES. Handbooks 7110.65, 7210.3, FAA Orders 8400.9 and 7110.98.

6. PROGRAM. Dependent converging instrument approach procedures will be developed by ATC in accordance with the following:

    a. Determine that the volume and complexity of aircraft operations requires the use of dependent converging instrument approaches and that no operational hardship on users or control facilities will result.

b. If runways intersect, coordinate with airport management to ensure that runway intersection identification markings are in accordance with appropriate standards.

c. At least 60 days before the effective date, publish a letter to airmen defining local procedures to be used. Additional means of publicizing local procedures (pilot meetings, etc.) shall be employed as per Handbook 7210.3, paragraph 423, "Coordination of ATC Procedures."

7. CRITERIA. The requirements for conducting dependent instrument approaches to converging runways are:

a. Radar availability

b. Precision instrument approach systems on each runway

c. Nonintersecting final approach courses

d. Modified ARTS displays to indicate specific DCIA fixes for each class of aircraft on each approach in accordance with the provisions given by the facility directive authorizing DCIA

e. A facility directive or Letter of Agreement specifying as a minimum:

(1) each applicable runway configuration

(2) coordination requirements

(3) weather minima applicable to each configuration if different from published minima

Because of local, site specific considerations, facility management may wish to establish higher minima than published on the Standard Instrument Approach Procedures (SIAP) to preclude, to the extent feasible, the possibility of a weather related missed approach.

f. Approach control shall have direct communications capability with the local controller at locations where separation responsibility has not been delegated to the tower.

8. PROCEDURES. Dependent instrument approaches to converging runways may be authorized under the following conditions:

a. Only straight-in approaches will be made.

b. Navigational aids and appropriate frequencies are operating normally.

c. Aircraft are informed on initial contact or as soon as possible thereafter that dependent converging approaches are in use. This information may be provided through ATIS.

d. Weather activity that could impact the final approach courses is closely monitored.

e. No two aircraft (one on each approach) shall be permitted to be simultaneously present between their DCIA fix and missed approach point (MAP). When one aircraft is between its DCIA fix and MAP, the controller shall issue a go-around (in accordance with the provisions given by the facility directive authorizing DCIA) to an aircraft on the converging approach if that aircraft has passed its DCIA fix. Otherwise, both aircraft will be permitted to proceed to their published missed approach points.

f. If the leading aircraft initiates a missed approach procedure, the controller shall issue the succeeding aircraft (on the opposite approach) explicit instructions in accordance with the provisions given by the facility directive authorizing DCIA.

9. GENERAL. Record any occurrence of consecutive missed approaches on the Daily Record of Facility Operation, Form 7230.4, and submit a brief summary to the Procedures Division, ATO-300, through the appropriate regional air traffic division, within 20 days. Include aircraft ID, type, weather, reason for each of the missed approaches, and any other pertinent data.

"Consecutive missed approaches" are defined as two missed approaches by aircraft on two converging approaches occurring within 90 seconds of each other.

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GLOSSARY

Acronyms

ARTS	Automated Radar Terminal System
ATC	Air Traffic Control
ATIS	Automated Terminal Information Service
DCIA	Dependent Converging Instrument Approaches (Alternating Approaches)
DH	Decision Height
FAA	Federal Aviation Administration
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
MAP	Missed Approach Point
RWY	Runway
SCIA	Simultaneous Converging Instrument Approaches (see TERPS+3)
SIAP	Standard Instrument Approach Procedures
TERPS	Terminal Instrument Procedures Standards
TERPS+3	TERPS+3 Approach Procedure (see SCIA)
TRACON	Terminal Radar Approach Control Facility
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

Abbreviations

brkwy.	Breakaway Point
ft	foot, feet
kt	knot(s)
mi	mile(s)
min	minute(s)
nmi	nautical mile(s)
pct	percent (%)
sec	second(s)
thresh.	threshold